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(54) Title: INORGANIC HYDROGEN AND HYDROGEN POLYMER COMPOUNDS AND APPLICATIONS THEREOF

## (57) Abstract

Compounds are provided comprising at least one neutral, positive, or negative hydrogen species having a binding energy greater than its corresponding ordinary hydrogen species, or greater than any hydrogen species for which the corresponding ordinary hydrogen species is unstable or is not observed. Compounds comprise at least one increased binding energy hydrogen species and at least one other atom, molecule, or ion other than an increased binding energy hydrogen species. One group of such compounds contains one or more increased binding energy hydrogen species selected from the group consisting of  $H_n$ ,  $H^{-n}$ , and  $H^{+n}$ , where n is a positive integer, with the proviso that n is greater than 1 when H has a positive charge. Another group of such compounds may have the formula  $[MH_mM'X]_n$  wherein m and n are each an integer, M and M' are each an alkali or alkaline earth cation, X is a singly or doubly negative charged anion, and the hydrogen content  $H_m$  of the compound comprises at least one increased binding energy hydrogen species. Method of forming the compounds and numerous applications are disclosed.

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INORGANIC HYDROGEN AND HYDROGEN POLYMER COMPOUNDS AND  
APPLICATIONS THEREOF

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INORGANIC-HYDROGEN-POLYMER AND HYDROGEN-POLYMER COMPOUNDS  
AND APPLICATIONS THEREOF

I. INTRODUCTION

5

1. Field of the Invention:

This invention relates to novel compositions of matter comprising new forms of hydrogen.

10    2. Background of the Invention

2.1 Hydrinos

A hydrogen atom having a binding energy given by

$$\text{Binding Energy} = \frac{13.6 \text{ eV}}{\left(\frac{1}{p}\right)^2} \quad (1)$$

where  $p$  is an integer greater than 1, preferably from 2 to 200, is disclosed in Mills, R., The Grand Unified Theory of Classical Quantum Mechanics, January 1999 Edition (" '99 Mills GUT"), provided by BlackLight Power, Inc., 493 Old Trenton Road, Cranbury, NJ, 08512; and in prior PCT applications PCT/US98/14029; PCT/US96/07949; PCT/US94/02219; PCT/US91/8496; PCT/US90/1998; and prior US Patent Applications Ser. No. 09/225,687, filed on January 6, 1999; Ser. No. 60/095,149, filed August 3, 1998; Ser. No. 60/101,651, filed September 24, 1998; Ser. No. 60/105,752, filed October 26, 1998; Ser. No. 60/113,713, filed December 24, 1998; Ser. No. 60/123,835, filed March 11, 1999; Ser. No. 60/130,491, filed April 22, 1999; Ser. No. 60/141,036, filed June 29, 1999; Serial No. 09/009,294 filed January 20, 1998; Serial No. 09/111,160 filed July 7, 1998; Serial No. 09/111,170 filed July 7, 1998; Serial No. 09/111,016 filed July 7, 1998; Serial No. 09/111,003 filed July 7, 1998; Serial No. 09/110,694 filed July 7, 1998; Serial No. 09/110,717 filed July 7, 1998; Serial No. 60/053378 filed July 22, 1997; Serial No. 60/068913 filed December 29, 1997; Serial No. 60/090239 filed June 22, 1998; Serial No. 09/009455 filed January 20, 1998; Serial No. 09/110,678 filed July 7, 1998; Serial No. 60/053,307 filed July 22, 1997; Serial No. 60/068918 filed December 29, 1997; Serial No. 60/080,725 filed April 3, 1998; Serial No. 09/181,180 filed October 28, 1998; Serial No. 60/063,451 filed October 29, 1997; Serial No. 09/008,947 filed

January 20, 1998; Serial No. 60/074,006 filed February 9, 1998; Serial No. 60/080,647 filed April 3, 1998; Serial No. 09/009,837 filed January 20, 1998; Serial No. 08/822,170 filed March 27, 1997; Serial No. 08/592,712 filed January 26, 1996; Serial No. 08/467,051 filed on June 6, 1995; Serial 5 No. 08/416,040 filed on April 3, 1995; Serial No. 08/467,911 filed on June 6, 1995; Serial No. 08/107,357 filed on August 16, 1993; Serial No. 08/075,102 filed on June 11, 1993; Serial No. 07/626,496 filed on December 12, 1990; Serial No. 07/345,628 filed April 28, 1989; Serial No. 10 07/341,733 filed April 21, 1989 the entire disclosures of which are all incorporated herein by reference (hereinafter "Mills Prior Publications"). The binding energy, of an atom, ion or molecule, also known as the ionization energy, is the energy required to remove one electron from the atom, ion or molecule.

A hydrogen atom having the binding energy given in Eq. (1) is 15 hereafter referred to as a hydrino atom or hydrino. The designation for a hydrino of radius  $\frac{a_H}{p}$ , where  $a_H$  is the radius of an ordinary hydrogen atom and  $p$  is an integer, is  $H\left[\frac{a_H}{p}\right]$ . A hydrogen atom with a radius  $a_H$  is 20 hereinafter referred to as "ordinary hydrogen atom" or "normal hydrogen atom." Ordinary atomic hydrogen is characterized by its binding energy of 13.6 eV.

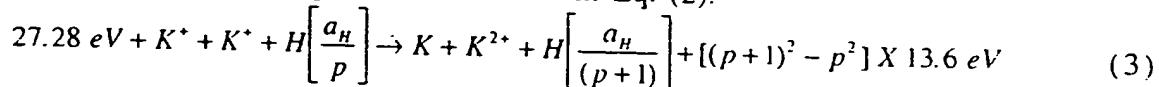
Hydrinos are formed by reacting an ordinary hydrogen atom with a catalyst having a net enthalpy of reaction of about

$$m \cdot 27.2 \text{ eV} \quad (2)$$

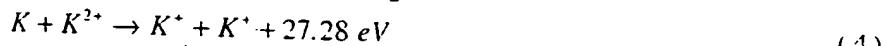
where  $m$  is an integer. This catalyst has also been referred to as an 25 energy hole or source of energy hole in Mills earlier filed Patent Applications. It is believed that the rate of catalysis is increased as the net enthalpy of reaction is more closely matched to  $m \cdot 27.2 \text{ eV}$ . It has been found that catalysts having a net enthalpy of reaction within  $\pm 10\%$ , preferably  $\pm 5\%$ , of  $m \cdot 27.2 \text{ eV}$  are suitable for most applications.

This catalysis releases energy from the hydrogen atom with a commensurate decrease in size of the hydrogen atom,  $r_n = n a_H$ . For example, the catalysis of  $H(n=1)$  to  $H(n=1/2)$  releases 40.8 eV, and the hydrogen radius decreases from  $a_H$  to  $\frac{1}{2}a_H$ . One such catalytic system involves potassium. The second ionization energy of potassium is 31.63 eV;

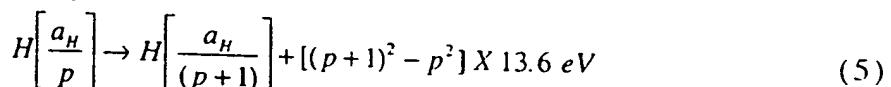
and  $K^+$  releases 4.34 eV when it is reduced to  $K$ . The combination of reactions  $K^+$  to  $K^{2+}$  and  $K^+$  to  $K$ , then, has a net enthalpy of reaction of 27.28 eV, which is equivalent to  $m=1$  in Eq. (2).



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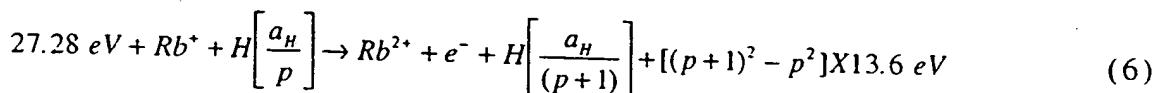


The overall reaction is



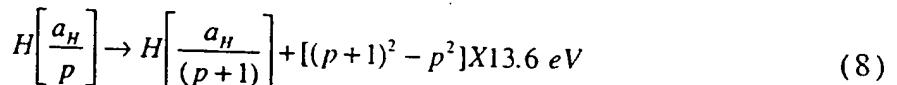
Rubidium ion ( $Rb^+$ ) is also a catalyst because the second ionization energy of rubidium is 27.28 eV. In this case, the catalysis reaction is

10



And, the overall reaction is

15



The energy given off during catalysis is much greater than the energy lost to the catalyst. The energy released is large as compared to conventional chemical reactions. For example, when hydrogen and oxygen gases undergo combustion to form water

20



25

the known enthalpy of formation of water is  $\Delta H_f = -286 \text{ kJ/mole}$  or 1.48 eV per hydrogen atom. By contrast, each ( $n=1$ ) ordinary hydrogen atom undergoing catalysis releases a net of 40.8 eV. Moreover, further catalytic transitions may occur:  $n = \frac{1}{2} \rightarrow \frac{1}{3}$ ,  $\frac{1}{3} \rightarrow \frac{1}{4}$ ,  $\frac{1}{4} \rightarrow \frac{1}{5}$ , and so on. Once catalysis begins, hydrinos autocatalyze further in a process called disproportionation. This mechanism is similar to that of an inorganic ion catalysis. But, hydrino catalysis should have a higher reaction rate than that of the inorganic ion catalyst due to the better match of the enthalpy to  $m=27.2 \text{ eV}$ .

30

## 2.2 Hydride Ions

A hydride ion comprises two indistinguishable electrons bound to a proton. Alkali and alkaline earth hydrides react violently with water to release hydrogen gas which burns in air ignited by the heat of the reaction with water. Typically metal hydrides decompose upon heating at a temperature well below the melting point of the parent metal.

## II. SUMMARY OF THE INVENTION

An objective of the present invention is to provide novel compounds that can be used in batteries, fuel cells, cutting materials, light weight high strength structural materials and synthetic fibers, corrosion resistant coatings, heat resistant coatings, xerographic compounds, proton source, photoluminescent compounds, phosphors for lighting, ultraviolet and visible light source, photoconductors, photovoltaics, chemiluminescent compounds, fluorescent compounds, optical coatings, optical filters, extreme ultraviolet laser media, fiber optic cables, magnets and magnetic computer storage media, superconductors, and etching agents, masking agents, agents to purify silicon, dopants in semiconductor fabrication, cathodes for thermionic generators, fuels, explosives, and propellants.

Another objective is to provide compounds which may be useful in chemical synthetic processing methods and refining methods.

A further objective is to provide the negative ion of the electrolyte of a high voltage electrolytic cell.

A further objective is to provide a compound having a selective reactivity in forming bonds with specific isotopes to provide a means to purify desired isotopes of elements.

The above objectives and other objectives are achieved by novel compounds and molecular ions comprising

- (a) at least one neutral, positive, or negative hydrogen species (hereinafter "increased binding energy hydrogen species") having a binding energy
  - (i) greater than the binding energy of the corresponding ordinary hydrogen species, or
  - (ii) greater than the binding energy of any hydrogen species for which the corresponding ordinary hydrogen species is unstable or is not observed because the ordinary hydrogen species' binding energy is less than thermal energies at ambient conditions (standard temperature

and pressure, STP), or is negative; and

(b) at least one other element. The compounds of the invention are hereinafter referred to as "increased binding energy hydrogen compounds".

5 By "other element" in this context is meant an element other than an increased binding energy hydrogen species. Thus, the other element can be an ordinary hydrogen species, or any element other than hydrogen. In one group of compounds, the other element and the increased binding energy hydrogen species are neutral. In another group

10 of compounds, the other element and increased binding energy hydrogen species are charged such that the other element provides the balancing charge to form a neutral compound. The former group of compounds is characterized by molecular and coordinate bonding; the latter group is characterized by ionic bonding.

15 Also provided are novel compounds and molecular ions comprising  
(a) at least one neutral, positive, or negative hydrogen species  
(hereinafter "increased binding energy hydrogen species") having a total energy

20 (i) greater than the total energy of the corresponding ordinary hydrogen species, or

(ii) greater than the total energy of any hydrogen species for which the corresponding ordinary hydrogen species is unstable or is not observed because the ordinary hydrogen species' total energy is less than thermal energies at ambient conditions, or is negative; and

25 (b) at least one other element.

The total energy of the hydrogen species is the sum of the energies to remove all of the electrons from the hydrogen species. The hydrogen species according to the present invention has a total energy greater than the total energy of the corresponding ordinary hydrogen species. The hydrogen species having an increased total energy according to the present invention is also referred to as an "increased binding energy hydrogen species" even though some embodiments of the hydrogen species having an increased total energy may have a first electron binding energy less than the first electron binding energy of the corresponding ordinary hydrogen species. For example, the hydride ion of Eq. (10) for  $p=24$  has a first binding energy that is less than the first binding energy of ordinary hydride ion, while the total energy of the

hydride ion of Eq. (10) for  $p=24$  is much greater than the total energy of the corresponding ordinary hydride ion.

Also provided are novel compounds and molecular ions comprising

(a) a plurality of neutral, positive, or negative hydrogen species

5 (hereinafter "increased binding energy hydrogen species") having a binding energy

(i) greater than the binding energy of the corresponding ordinary hydrogen species, or

(ii) greater than the binding energy of any hydrogen species

10 for which the corresponding ordinary hydrogen species is unstable or is not observed because the ordinary hydrogen species' binding energy is less than thermal energies at ambient conditions or is negative; and

(b) optionally one other element. The compounds of the invention are hereinafter referred to as "increased binding energy hydrogen

15 compounds".

The increased binding energy hydrogen species can be formed by reacting one or more hydrino atoms with one or more of an electron, hydrino atom, a compound containing at least one of said increased binding energy hydrogen species, and at least one other atom, molecule, or ion other than an increased binding energy hydrogen species.

Also provided are novel compounds and molecular ions comprising

(a) a plurality of neutral, positive, or negative hydrogen species

(hereinafter "increased binding energy hydrogen species") having a total energy

25 (i) greater than the total energy of ordinary molecular hydrogen, or

(ii) greater than the total energy of any hydrogen species for which the corresponding ordinary hydrogen species is unstable or is not observed because the ordinary hydrogen species' total energy is less than thermal energies at ambient conditions or is negative; and

30 (b) optionally one other element. The compounds of the invention are hereinafter referred to as "increased binding energy hydrogen compounds".

The total energy of the increased total energy hydrogen species is the sum of the energies to remove all of the electrons from the increased total energy hydrogen species. The total energy of the ordinary hydrogen species is the sum of the energies to remove all of the electrons from the

ordinary hydrogen species. The increased total energy hydrogen species is referred to as an increased binding energy hydrogen species, even though some of the increased binding energy hydrogen species may have a first electron binding energy less than the first electron binding energy of ordinary molecular hydrogen. However, the total energy of the increased binding energy hydrogen species is much greater than the total energy of ordinary molecular hydrogen.

In one embodiment of the invention, the increased binding energy hydrogen species can be  $H_n$ , and  $H_n^-$  where n is a positive integer, or  $H_n^+$  where n is a positive integer greater than one. Preferably, the increased binding energy hydrogen species is  $H_n$  and  $H_n^-$  where n is an integer from one to about  $1 \times 10^6$ , more preferably one to about  $1 \times 10^4$ , even more preferably one to about  $1 \times 10^2$ , and most preferably one to about 10, and  $H_n^+$  where n is an integer from two to about  $1 \times 10^6$ , more preferably two to about  $1 \times 10^4$ , even more preferably two to about  $1 \times 10^2$ , and most preferably two to about 10. A specific example of  $H_n^-$  is  $H_{16}^-$ .

In an embodiment of the invention, the increased binding energy hydrogen species can be  $H_n^{m-}$  where n and m are positive integers and  $H_n^{m+}$  where n and m are positive integers with  $m < n$ . Preferably, the increased binding energy hydrogen species is  $H_n^{m-}$  where n is an integer from one to about  $1 \times 10^6$ , more preferably one to about  $1 \times 10^4$ , even more preferably one to about  $1 \times 10^2$ , and most preferably one to about 10 and m is an integer from one to 100, one to ten, and  $H_n^{m+}$  where n is an integer from two to about  $1 \times 10^6$ , more preferably two to about  $1 \times 10^4$ , even more preferably two to about  $1 \times 10^2$ , and most preferably two to about 10 and m is one to about 100, preferably one to ten.

According to a preferred embodiment of the invention, a compound is provided, comprising at least one increased binding energy hydrogen species selected from the group consisting of (a) hydride ion having a binding energy according to Eq. (10) that is greater than the binding of ordinary hydride ion (about 0.8 eV) for  $p=2$  up to 23, and less for  $p=24$  ("increased binding energy hydride ion" or "hydrino hydride ion"); (b) hydrogen atom having a binding energy greater than the binding energy of ordinary hydrogen atom (about 13.6 eV) ("increased binding energy hydrogen atom" or "hydrino"); (c) hydrogen molecule having a first binding energy greater than about 15.5 eV ("increased binding energy hydrogen molecule" or "dihydrino"); and (d) molecular hydrogen ion

having a binding energy greater than about 16.4 eV ("increased binding energy molecular hydrogen ion" or "dihydrino molecular ion").

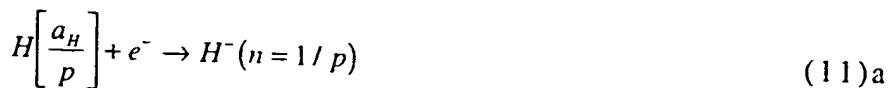
- The compounds of the present invention are capable of exhibiting one or more unique properties which distinguishes them from the corresponding compound comprising ordinary hydrogen, if such ordinary hydrogen compound exists. The unique properties include, for example, (a) a unique stoichiometry; (b) unique chemical structure; (c) one or more extraordinary chemical properties such as conductivity, melting point, boiling point, density, and refractive index; (d) unique reactivity to other elements and compounds; (e) enhanced stability at room temperature and above; and/or (f) enhanced stability in air and/or water. Methods for distinguishing the increased binding energy hydrogen-containing compounds from compounds of ordinary hydrogen include: 1.) elemental analysis, 2.) solubility, 3.) reactivity, 4.) melting point, 5.) boiling point, 6.) vapor pressure as a function of temperature, 7.) refractive index, 8.) X-ray photoelectron spectroscopy (XPS), 9.) gas chromatography, 10.) X-ray diffraction (XRD), 11.) calorimetry, 12.) infrared spectroscopy (IR), 13.) Raman spectroscopy, 14.) Mossbauer spectroscopy, 15.) extreme ultraviolet (EUV) emission and absorption spectroscopy, 16.) ultraviolet (UV) emission and absorption spectroscopy, 17.) visible emission and absorption spectroscopy, 18.) nuclear magnetic resonance spectroscopy, 19.) gas phase mass spectroscopy of a heated sample (solids probe and direct exposure probe quadrapole and magnetic sector mass spectroscopy), 20.) time-of-flight-secondary-ion-mass-spectroscopy (TOFSIMS), 21.) electrospray-ionization-time-of-flight-mass-spectroscopy (ESITOFMS), 22.) thermogravimetric analysis (TGA), 23.) differential thermal analysis (DTA), 24.) differential scanning calorimetry (DSC), 25.) liquid chromatography/mass spectroscopy (LCMS), and/or 26.) gas chromatography/mass spectroscopy (GCMS).
- According to the present invention, a hydrino hydride ion ( $H^-$ ) having a binding energy according to Eq. (10) that is greater than the binding of ordinary hydride ion (about 0.8 eV) for  $p=2$  up to 23, and less for  $p=24$  ( $H^-$ ) is provided. For  $p=2$  to  $p=24$  of Eq. (10), the hydride ion binding energies are respectively 3, 6.6, 11.2, 16.7, 22.8, 29.3, 36.1, 42.8, 49.4, 55.5, 61.0, 65.6, 69.2, 71.5, 72.4, 715, 68.8, 64.0, 56.8, 47.1, 34.6, 19.2, and 0.65 eV. Compositions comprising the novel hydride ion are also provided.

The binding energy of the novel hydrino hydride ion can be represented by the following formula:

$$\text{Binding Energy} = \frac{\hbar^2 \sqrt{s(s+1)}}{8\mu_r a_0^2 \left[ \frac{1 + \sqrt{s(s+1)}}{p} \right]^3} - \frac{\pi \mu_0 e^2 \hbar^2}{m_e^2 a_0^3} \left( 1 + \frac{2^2}{\left[ \frac{1 + \sqrt{s(s+1)}}{p} \right]^3} \right) \quad (10)$$

where  $p$  is an integer greater than one,  $s = 1/2$ ,  $\pi$  is pi,  $\hbar$  is Planck's constant bar,  $\mu_0$  is the permeability of vacuum,  $m_e$  is the mass of the electron,  $\mu_r$  is the reduced electron mass,  $a_0$  is the Bohr radius, and  $e$  is the elementary charge.

10 The hydrino hydride ion of the present invention can be formed by the reaction of an electron source with a hydrino, that is, a hydrogen atom having a binding energy of about  $\frac{13.6 \text{ eV}}{n^2}$ , where  $n = \frac{1}{p}$  and  $p$  is an integer greater than 1. The hydrino hydride ion is represented by  $H^- (n = 1/p)$  or  $H^- (1/p)$ :



15 The hydrino hydride ion is distinguished from an ordinary hydride ion comprising an ordinary hydrogen nucleus and two electrons having a binding energy of about 0.8 eV. The latter is hereafter referred to as "ordinary hydride ion" or "normal hydride ion". The hydrino hydride ion comprises a hydrogen nucleus including protium, deuterium, or tritium, and two indistinguishable electrons at a binding energy according to Eq. 20 (10).

The binding energies of the hydrino hydride ion,  $H^- (n = 1/p)$  as a function of  $p$ , where  $p$  is an integer, are shown in TABLE 1.

hydrogen species such as (a) a hydrogen atom having a binding energy of about  $\frac{13.6 \text{ eV}}{\left(\frac{1}{p}\right)^2}$ , preferably within  $\pm 10\%$ , more preferably  $\pm 5\%$ , where p is

an integer, preferably an integer from 2 to 200; (b) a hydride ion ( $H^-$ ) having a binding energy of about

5 
$$\frac{\hbar^2 \sqrt{s(s+1)}}{8\mu_e a_0^2 \left[ \frac{1 + \sqrt{s(s+1)}}{p} \right]^2} - \frac{\pi \mu_0 e^2 \hbar^2}{m_e^2 a_0^3} \left( 1 + \frac{2^2}{\left[ \frac{1 + \sqrt{s(s+1)}}{p} \right]^3} \right),$$
 preferably within  $\pm 10\%$ , more

preferably  $\pm 5\%$ , where p is an integer, preferably an integer from 2 to 200,  $s = 1/2$ ,  $\pi$  is pi,  $\hbar$  is Planck's constant bar,  $\mu_0$  is the permeability of vacuum,  $m_e$  is the mass of the electron,  $\mu_e$  is the reduced electron mass,  $a_0$  is the Bohr radius, and  $e$  is the elementary charge; (c)  $H_4^+(1/p)$ ; (d) a

10 trihydrino molecular ion,  $H_3^+(1/p)$ , having a binding energy of about  $\frac{22.6}{\left(\frac{1}{p}\right)^2} \text{ eV}$  preferably within  $\pm 10\%$ , more preferably  $\pm 5\%$ , where p is an

integer, preferably an integer from 2 to 200; (e) a dihydrino having a binding energy of about  $\frac{15.5}{\left(\frac{1}{p}\right)^2} \text{ eV}$  preferably within  $\pm 10\%$ , more preferably

15  $\pm 5\%$ , where p is an integer, preferably and integer from 2 to 200; (f) a dihydrino molecular ion with a binding energy of about  $\frac{16.4}{\left(\frac{1}{p}\right)^2} \text{ eV}$

preferably within  $\pm 10\%$ , more preferably  $\pm 5\%$ , where p is an integer, preferably an integer from 2 to 200.

20 The compounds of the present invention are preferably greater than 50 atomic percent pure. More preferably, the compounds are greater than 90 atomic percent pure. Most preferably, the compounds are greater than 98 atomic percent pure.

25 According to one embodiment of the invention wherein the compound comprises a negatively charged increased binding energy hydrogen species, the compound further comprises one or more cations, such as a proton, ordinary  $H_2^+$ , or ordinary  $H_3^+$ .

The compounds of the invention further comprise one or more

TABLE I. The representative binding energy of the hydrino hydride ion  $H^- (n = 1/p)$  as a function of  $p$ , Eq. (10).

	Hydride Ion	$r_1$ ( $a_0$ ) <sup>a</sup>	Binding Energy <sup>b</sup> (eV)	Wavelength (nm)
5	$H^- (n = 1/2)$	0.9330	3.047	407
	$H^- (n = 1/3)$	0.6220	6.610	188
	$H^- (n = 1/4)$	0.4665	11.23	110
10	$H^- (n = 1/5)$	0.3732	16.70	74.2
	$H^- (n = 1/6)$	0.3110	22.81	54.4
	$H^- (n = 1/7)$	0.2666	29.34	42.3
	$H^- (n = 1/8)$	0.2333	36.08	34.4
	$H^- (n = 1/9)$	0.2073	42.83	28.9
15	$H^- (n = 1/10)$	0.1866	49.37	25.1
	$H^- (n = 1/11)$	0.1696	55.49	22.3
	$H^- (n = 1/12)$	0.1555	60.97	20.3
	$H^- (n = 1/13)$	0.1435	65.62	18.9
	$H^- (n = 1/14)$	0.1333	69.21	17.9
20	$H^- (n = 1/15)$	0.1244	71.53	17.3
	$H^- (n = 1/16)$	0.1166	72.38	17.1

<sup>a</sup> Equation (51), *infra*.

<sup>b</sup> Equation (52), *infra*.

25

Novel compounds are provided comprising one or more hydrino hydride ions and one or more other elements. Such a compound is referred to as a hydrino hydride compound.

30 Ordinary hydrogen species are characterized by the following binding energies (a) hydride ion, 0.754 eV ("ordinary hydride ion"); (b) hydrogen atom ("ordinary hydrogen atom"), 13.6 eV; (c) diatomic hydrogen molecule, 15.46 eV ("ordinary hydrogen molecule"); (d) hydrogen molecular ion, 16.4 eV ("ordinary hydrogen molecular ion"); and (e)  $H_3^+$ , 22.6 eV ("ordinary trihydrogen molecular ion"). Herein, with reference to forms of hydrogen, "normal" and "ordinary" are synonymous.

35 According to a further preferred embodiment of the invention, a compound is provided comprising at least one increased binding energy

normal hydrogen atoms and/or normal hydrogen molecules, in addition to the increased binding energy hydrogen species.

The compound may have the formula  $MXM' H_n$  wherein n is an integer from 1 to 6, M is an alkali or alkaline earth cation, X is a singly or doubly negative charged anion, M' is Si, Al, Ni, a transition element, an inner transition element, or a rare earth element, and the hydrogen content  $H_n$  of the compound comprises at least one increased binding energy hydrogen species.

The compound may have the formula  $MAIH_n$  wherein n is an integer from 1 to 6, M is an alkali or alkaline earth cation and the hydrogen content  $H_n$  of the compound comprises at least one increased binding energy hydrogen species.

The compound may have the formula  $MH_n$  wherein n is an integer from 1 to 6, M is a transition element, an inner transition element, a rare earth element, or Ni, and the hydrogen content  $H_n$  of the compound comprises at least one increased binding energy hydrogen species.

The compound may have the formula  $MNiH_n$  wherein n is an integer from 1 to 6, M is an alkali cation, alkaline earth cation, silicon, or aluminum, and the hydrogen content  $H_n$  of the compound comprises at least one increased binding energy hydrogen species.

The compound may have the formula  $MM' H_n$  wherein n is an integer from 1 to 6, M is an alkali cation, alkaline earth cation, silicon, or aluminum, M' is a transition element, inner transition element, or a rare earth element cation, and the hydrogen content  $H_n$  of the compound comprises at least one increased binding energy hydrogen species.

The compound may have the formula  $MXAIX' H_n$  wherein n is 1 or 2, M is an alkali or alkaline earth cation, X and X' are either a singly negative charged anion or a doubly negative charged anion, and the hydrogen content  $H_n$  of the compound comprises at least one increased binding energy hydrogen species.

The compound may have the formula  $TiH_n$  wherein n is an integer from 1 to 4, and the hydrogen content  $H_n$  of the compound comprises at least one increased binding energy hydrogen species.

The compound may have the formula  $AlH_n$  wherein n is an integer from 1 to 4, and the hydrogen content  $H_n$  of the compound comprises at least one increased binding energy hydrogen species.

The compound may have the formula  $Al_2H_n$  wherein n is an integer

from 1 to 4, and the hydrogen content  $H_n$  of the compound comprises at least one increased binding energy hydrogen species.

5 The compound may have the formula  $[KH_mKCO_3]_n$  wherein m and n are each an integer, the compound contains at least one H, and the hydrogen content  $H_m$  of the compound comprises at least one increased binding energy hydrogen species.

10 The compound may have the formula  $[KH_mKNO_3]_n nX^-$  wherein m and n are each an integer, X is a singly negative charged anion, the compound contains at least one H, and the hydrogen content  $H_m$  of the compound comprises at least one increased binding energy hydrogen species.

15 The compound may have the formula  $[KHKNO_3]_n$  wherein n is an integer and the hydrogen content H of the compound comprises at least one increased binding energy hydrogen species.

20 The compound may have the formula  $[KHKOH]_n$  wherein n is an integer and the hydrogen content H of the compound comprises at least one increased binding energy hydrogen species.

25 The compound including an anion or cation may have the formula  $[MH_mM'X]_n$  wherein m and n are each an integer, M and M' are each an alkali or alkaline earth cation, X is a singly or doubly negative charged anion, the compound contains at least one H, and the hydrogen content  $H_m$  of the compound comprises at least one increased binding energy hydrogen species.

30 The compound including an anion or cation may have the formula  $[MH_mM'X]_{n'}^{m'+} n'X^-$  wherein m, m', n, and n' are each an integer, M and M' are each an alkali or alkaline earth cation, X and X' are a singly or doubly negative charged anion, the compound contains at least one H, and the hydrogen content  $H_m$  of the compound comprises at least one increased binding energy hydrogen species.

35 The compound including an anion or cation may have the formula  $[MH_mM'X]_{n'}^{m'-} n'M''^{++}$  wherein m, m', n, and n' are each an integer, M, M', and M'' are each an alkali or alkaline earth cation, X and X' are each a singly negative charged anion, the compound contains at least one H, and the hydrogen content  $H_m$  of the compound comprises at least one increased binding energy hydrogen species.

The compound including an anion or cation may have the formula

$[MH_m]^{m+} n^- X^-$  wherein m, m', n, and n' are each an integer, M is alkali or alkaline earth, organic, organometallic, inorganic, or ammonium cation, X is a singly or doubly negative charged anion, the compound contains at least one H, and the hydrogen content  $H_m$  of the compound comprises at least 5 one increased binding energy hydrogen species.

The compound including an anion or cation may have the formula  $[MH_m]^{m+} n^- M'^+$  wherein m, m', n, and n' are each an integer, M and M' are an alkali or alkaline earth, organic, organometallic, inorganic, or ammonium cation, the compound contains at least one H, and the 10 hydrogen content  $H_m$  of the compound comprises at least one increased binding energy hydrogen species.

The compound may have the formula  $M(H_{10})_n$  wherein n is an integer, M is other element such as any atom, molecule, or compound, and the hydrogen content  $(H_{10})_n$  of the compound comprises at least one 15 increased binding energy hydrogen species.

The compound may have the formula  $M(H_{10})_n$  wherein n is an integer, M is an increased binding energy hydrogen compound, and the hydrogen content  $(H_{10})_n$  of the compound comprises at least one increased binding energy hydrogen species.

20 The compound may have the formula  $M^+(H_{16})_n^-$  wherein n is an integer, M is other element such as an alkali, organic, organometallic, inorganic, or ammonium cation, and the hydrogen content  $(H_{16})_n^-$  of the compound comprises at least one increased binding energy hydrogen species.

25 The compound may have the formula  $M^+(H_{16})_n^-$  wherein n is an integer, M is an increased binding energy hydrogen compound, and the hydrogen content  $(H_{16})_n^-$  of the compound comprises at least one increased binding energy hydrogen species.

The compound may have the formula  $M(H_{16})_n$  wherein n is an 30 integer, M is other element such as any atom, molecule, or compound, and the hydrogen content  $(H_{16})_n$  of the compound comprises at least one increased binding energy hydrogen species.

The compound may have the formula  $M(H_{16})_n$  wherein n is an 35 integer, M is an increased binding energy hydrogen compound, and the hydrogen content  $(H_{16})_n$  of the compound comprises at least one increased

binding energy hydrogen species.

5 The compound may have the formula  $M(H_{24})_n$ , wherein n is an integer, M is other element such as any atom, molecule, or compound, and the hydrogen content  $(H_{24})_n$  of the compound comprises at least one increased binding energy hydrogen species.

10 The compound may have the formula  $M(H_{24})_n$ , wherein n is an integer, M is an increased binding energy hydrogen compound, and the hydrogen content  $(H_{24})_n$  of the compound comprises at least one increased binding energy hydrogen species.

15 The compound may have the formula  $M(H_{60})_n$ , wherein n is an integer, M is other element such as any atom, molecule, or compound, and the hydrogen content  $(H_{60})_n$  of the compound comprises at least one increased binding energy hydrogen species.

20 The compound may have the formula  $M(H_{60})_n$ , wherein n is an integer, M is an increased binding energy hydrogen compound, and the hydrogen content  $(H_{60})_n$  of the compound comprises at least one increased binding energy hydrogen species.

25 The compound may have the formula  $M(H_{70})_n$ , wherein n is an integer, M is other element such as any atom, molecule, or compound, and the hydrogen content  $(H_{70})_n$  of the compound comprises at least one increased binding energy hydrogen species.

30 The compound may have the formula  $M(H_{70})_n$ , wherein n is an integer, M is an increased binding energy hydrogen compound, and the hydrogen content  $(H_{70})_n$  of the compound comprises at least one increased binding energy hydrogen species.

35 The compound may have the formula  $M(H_{10})_q(H_{16})_r(H_{24})_s(H_{60})_t(H_{70})_u$ , wherein q, r, s, t, and u are each an integer including zero but not all zero, M is other element such as any atom, molecule, or compound, the monomers may be arranged in any order, and the hydrogen content  $(H_{10})_q(H_{16})_r(H_{24})_s(H_{60})_t(H_{70})_u$  of the compound comprises at least one increased binding energy hydrogen species.

40 The compound may have the formula  $M(H_{10})_q(H_{16})_r(H_{24})_s(H_{60})_t(H_{70})_u$ , wherein q, r, s, and t are each an integer including zero but not all zero, M is an increased binding energy hydrogen compound, the monomers may be arranged in any order, and the hydrogen content

$(H_{10})_q(H_{16})_r(H_{24})_s(H_{60})_t(H_{70})_u$  of the compound comprises at least one increased binding energy hydrogen species.

- The compound may have the formula  $MX$  wherein  $M$  is positive, neutral, or negative such as  $H_{16}$ ,  $H_{16}H$ ,  $H_{16}H_2$ ,  $H_{24}H_{23}$ ,  $OH_{22}$ ,  $OH_{23}$ ,  $OH_{24}$ ,
- 5  $MgH_2H_{16}$ ,  $NaH_3H_{16}$ ,  $H_{24}H_2O$ ,  $CNH_{16}$ ,  $CH_{30}$ ,  $SiH_4H_{16}$ ,  $(H_{16})_3H_{15}$ ,  $SiH_4(H_{16})_2(H_{16})_4$ ,  $H_{70}$ ,  
 $Si_2H_6H_{16}$ ,  $(SiH_4)_2H_{16}$ ,  $SiH_4(H_{16})_3$ ,  $CH_{70}$ ,  $NH_{69}$ ,  $NH_{70}$ ,  $NHH_{70}$ ,  $OH_{70}$ ,  $H_2OH_{70}$ ,  $FH_{70}$ ,  
 $H_3OH_{70}$ ,  $SiH_2H_{60}$ ,  $Si(H_{16})_3H_{15}$ ,  $Si(H_{16})_4$ ,  $Si_2H_6(H_{16})_2$ ,  $Si_2H_7(H_{16})_2$ ,  $SiH_3(H_{16})_4$ ,  
 $(SiH_4)_2(H_{16})_2$ ,  $O_2(H_{16})_4$ ,  $SiH_4(H_{16})_4$ ,  $NOH_{70}$ ,  $O_2H_{69}$ ,  $HONH_{70}$ ,  $O_2H_{70}$ ,  $H_2ONH_{70}$ ,  $H_3O_2H_{70}$ ,  
 $Si_2H_6(H_{24})_2$ ,  $Si_2H_6(H_{16})_3$ ,  $(SiH_4)_3H_{16}$ ,  $(SiH_4)_2(H_{16})_3$ ,  $(OH_{23})H_{16}H_{70}$ ,  $(OH_{24})H_{16}H_{70}$ ,
- 10  $Si_3H_{10}(H_{16})_2$ ,  $Si_2H_{70}$ ,  $Si_3H_{11}(H_{16})_2$ ,  $Si_2H_7(H_{16})_4$ ,  $(SiH_4)_3(H_{16})_2$ ,  $(SiH_4)_2(H_{16})_4$ ,  
 $NaOSiH_2(H_{16})_4$ ,  $NaKH H_{70}$ ,  $Si_2H_7(H_{70})$ ,  $Si_3H_9(H_{16})_3$ ,  $Si_3H_{10}(H_{16})_3$ ,  $Si_2H_6(H_{16})_5$ ,  
 $(SiH_4)_4H_{16}$ ,  $(SiH_4)_3(H_{16})_3$ ,  $Na_2OSiH_2(H_{16})_4$ ,  $Si_3H_8(H_{16})_4$ ,  $Na_2KH H_{70}$ ,  $Si_3H_9(H_{16})_4$ ,  
 $Na_2HKKH H_{70}$ ,  $SO(H_{16})_6(H_{15})$ ,  $SH_2(OH_{23})H_{16}H_{70}$ ,  $SO(H_{16})_7$ ,  $Mg_2H_2H_{23}H_{16}H_{70}$ ,  
 $(SiH_4)_4(H_{16})_2$ ,  $(SiH_4)_3(H_{16})_4$ ,  $KKH(H_{16})_7$ ,  $(SiH_4)_4(H_{16})_4$ ,  $(KH_2)_2(H_{16})_3H_{70}$ ,  $(NiH_2)_2HCl(H_{16})_2H_{70}$ ,  
 $Si_5OH_{102}$ ,  $(SiH_3)_7(H_{16})_5$ ,  $Na_3O_3(SiH_3)_{10}SiH(H_{16})_5$ ,  $X$  is other element, and the  
hydrogen content  $H$  of the compound comprises at least one increased binding energy hydrogen.
- 20 The compound may have the formula  $MX$  wherein  $M$  is positive, neutral, or negative such as  $H_{16}$ ,  $H_{16}H$ ,  $H_{16}H_2$ ,  $H_{24}H_{23}$ ,  $OH_{22}$ ,  $OH_{23}$ ,  $OH_{24}$ ,  
 $MgH_2H_{16}$ ,  $NaH_3H_{16}$ ,  $H_{24}H_2O$ ,  $CNH_{16}$ ,  $CH_{30}$ ,  $SiH_4H_{16}$ ,  $(H_{16})_3H_{15}$ ,  $SiH_4(H_{16})_2(H_{16})_4$ ,  $H_{70}$ ,  
 $Si_2H_6H_{16}$ ,  $(SiH_4)_2H_{16}$ ,  $SiH_4(H_{16})_3$ ,  $CH_{70}$ ,  $NH_{69}$ ,  $NH_{70}$ ,  $NHH_{70}$ ,  $OH_{70}$ ,  $H_2OH_{70}$ ,  $FH_{70}$ ,  
 $H_3OH_{70}$ ,  $SiH_2H_{60}$ ,  $Si(H_{16})_3H_{15}$ ,  $Si(H_{16})_4$ ,  $Si_2H_6(H_{16})_2$ ,  $Si_2H_7(H_{16})_2$ ,  $SiH_3(H_{16})_4$ ,  
 $(SiH_4)_2(H_{16})_2$ ,  $O_2(H_{16})_4$ ,  $SiH_4(H_{16})_4$ ,  $NOH_{70}$ ,  $O_2H_{69}$ ,  $HONH_{70}$ ,  $O_2H_{70}$ ,  $H_2ONH_{70}$ ,  $H_3O_2H_{70}$ ,  
 $Si_2H_6(H_{24})_2$ ,  $Si_2H_6(H_{16})_3$ ,  $(SiH_4)_3H_{16}$ ,  $(SiH_4)_2(H_{16})_3$ ,  $(OH_{23})H_{16}H_{70}$ ,  $(OH_{24})H_{16}H_{70}$ ,  
 $Si_3H_{10}(H_{16})_2$ ,  $Si_2H_{70}$ ,  $Si_3H_{11}(H_{16})_2$ ,  $Si_2H_7(H_{16})_4$ ,  $(SiH_4)_3(H_{16})_2$ ,  $(SiH_4)_2(H_{16})_4$ ,  
 $NaOSiH_2(H_{16})_4$ ,  $NaKH H_{70}$ ,  $Si_2H_7(H_{70})$ ,  $Si_3H_9(H_{16})_3$ ,  $Si_3H_{10}(H_{16})_3$ ,  $Si_2H_6(H_{16})_5$ ,  
 $(SiH_4)_4H_{16}$ ,  $(SiH_4)_3(H_{16})_3$ ,  $Na_2OSiH_2(H_{16})_4$ ,  $Si_3H_8(H_{16})_4$ ,  $Na_2KH H_{70}$ ,  $Si_3H_9(H_{16})_4$ ,  
 $Na_2HKKH H_{70}$ ,  $SO(H_{16})_6(H_{15})$ ,  $SH_2(OH_{23})H_{16}H_{70}$ ,  $SO(H_{16})_7$ ,  $Mg_2H_2H_{23}H_{16}H_{70}$ ,  
 $(SiH_4)_4(H_{16})_2$ ,  $(SiH_4)_3(H_{16})_4$ ,  $KH_3O(H_{16})_2H_{70}$ ,  $KH_5O(H_{16})_2H_{70}$ ,  $K(OH_{23})H_{16}H_{70}$ ,  $K_2OH H_{70}$ ,  
 $NaKHO_2H_{70}$ ,  $NaOHNaO_2 H_{70}$ ,  $HNO_3 O_2 H_{70}$ ,  $Rb(H_{16})_5$ ,  $Si_3H_{11}H_{70}$ ,  $KNO_2(H_{16})_5$ ,  
 $(SiH_4)_4(H_{16})_3$ ,  $KKH(H_{16})_7$ ,  $(SiH_4)_4(H_{16})_4$ ,  $(KH_2)_2(H_{16})_3H_{70}$ ,  $(NiH_2)_2HCl(H_{16})_2H_{70}$ ,  
 $Si_5OH_{102}$ ,  $(SiH_3)_7(H_{16})_5$ ,  $Na_3O_3(SiH_3)_{10}SiH(H_{16})_5$ ,  $X$  is an increased binding energy  
35 hydrogen compound, and the hydrogen content  $H$  of the compound

comprises at least one increased binding energy hydrogen.

- The compound may have the formula  $M(H_x)_n$  wherein n is an integer, x is an integer from 8 to 12, M is other element such as any atom, molecule, or compound, and the hydrogen content  $(H_x)_n$  of the compound
- 5 comprises at least one increased binding energy hydrogen species.
- The compound may have the formula  $M(H_x)_n$  wherein n is an integer, x is an integer from 8 to 12, M is an increased binding energy hydrogen compound, and the hydrogen content  $(H_x)_n$  of the compound comprises at least one increased binding energy hydrogen species.
- 10 The compound may have the formula  $M^+(H_x)_n^-$  wherein n is an integer, x is an integer from 14 to 18, M is other element such as an alkali, organic, organometallic, inorganic, or ammonium cation, and the hydrogen content  $(H_x)_n^-$  of the compound comprises at least one increased binding energy hydrogen species.
- 15 The compound may have the formula  $M^+(H_x)_n^-$  wherein n is an integer, x is an integer from 14 to 18, M is an increased binding energy hydrogen compound, and the hydrogen content  $(H_x)_n^-$  of the compound comprises at least one increased binding energy hydrogen species.
- The compound may have the formula  $M(H_x)_n$  wherein n is an
- 20 integer, x is an integer from 14 to 18, M is other element such as any atom, molecule, or compound, and the hydrogen content  $(H_x)_n$  of the compound comprises at least one increased binding energy hydrogen species.
- The compound may have the formula  $M(H_x)_n$  wherein n is an
- 25 integer, x is an integer from 14 to 18, M is an increased binding energy hydrogen compound, and the hydrogen content  $(H_x)_n$  of the compound comprises at least one increased binding energy hydrogen species.
- The compound may have the formula  $M(H_x)_n$  wherein n is an
- 30 integer, x is an integer from 22 to 26, M is other element such as any atom, molecule, or compound, and the hydrogen content  $(H_x)_n$  of the compound comprises at least one increased binding energy hydrogen species.
- The compound may have the formula  $M(H_x)_n$  wherein n is an
- 35 integer, x is an integer from 22 to 26, M is an increased binding energy hydrogen compound, and the hydrogen content  $(H_x)_n$  of the compound

comprises at least one increased binding energy hydrogen species.

- The compound may have the formula  $M(H_x)_n$  wherein n is an integer, x is an integer from 58 to 62, M is other element such as any atom, molecule, or compound, and the hydrogen content  $(H_x)_n$  of the compound comprises at least one increased binding energy hydrogen species.

- 5 The compound may have the formula  $M(H_x)_n$  wherein n is an integer, x is an integer from 58 to 62, M is an increased binding energy hydrogen compound, and the hydrogen content  $(H_x)_n$  of the compound comprises at least one increased binding energy hydrogen species.

- 10 The compound may have the formula  $M(H_x)_n$  wherein n is an integer, x is an integer from 58 to 62, M is other element such as any atom, molecule, or compound, and the hydrogen content  $(H_x)_n$  of the compound comprises at least one increased binding energy hydrogen species.

- 15 The compound may have the formula  $M(H_x)_n$  wherein n is an integer, x is an integer from 68 to 72, M is other element such as any atom, molecule, or compound, and the hydrogen content  $(H_x)_n$  of the compound comprises at least one increased binding energy hydrogen species.

- 20 The compound may have the formula  $M(H_x)_q(H_{x'})_r(H_y)_s(H_{y'})_t(H_z)_u$  wherein q, r, s, t, and u are each an integer including zero but not all zero, x is an integer from 8 to 12, x' is an integer from 14 to 18, y is an integer from 22 to 26, y' is an integer from 58 to 62, z is an integer from 68 to 72, M is other element such as any atom, molecule, or compound, the monomers may be arranged in any order, and the hydrogen content  $(H_x)_q(H_{x'})_r(H_y)_s(H_{y'})_t(H_z)_u$  of the compound comprises at least one increased binding energy hydrogen species.

- 25 The compound may have the formula  $M(H_x)_q(H_{x'})_r(H_y)_s(H_{y'})_t(H_z)_u$  wherein q, r, s, t, and u are each an integer including zero but not all zero, x is an integer from 8 to 12, x' is an integer from 14 to 18, y is an integer from 22 to 26, y' is an integer from 58 to 62, z is an integer from 68 to 72, M is other element such as any atom, molecule, or compound, the monomers may be arranged in any order, and the hydrogen content  $(H_x)_q(H_{x'})_r(H_y)_s(H_{y'})_t(H_z)_u$  of the compound comprises at least one increased binding energy hydrogen species.

- 30 The compound may have the formula  $M(H_x)_q(H_{x'})_r(H_y)_s(H_{y'})_t(H_z)_u$  wherein q, r, s, t, and u are each an integer including zero but not all zero, x is an integer from 8 to 12, x' is an integer from 14 to 18, y is an integer from 22 to 26, y' is an integer from 58 to 62, z is an integer from 68 to 72, M is an increased binding energy hydrogen compound, the monomers may be arranged in any order, and the hydrogen content  $(H_x)_q(H_{x'})_r(H_y)_s(H_{y'})_t(H_z)_u$  of the compound comprises at least one increased binding energy hydrogen species.

- 35 The compound may have the formula  $M(H_x)_q(H_{x'})_r(H_y)_s(H_{y'})_t(H_z)_u$  wherein q, r, s, t, and u are each an integer including zero but not all zero, x is an integer from 8 to 12, x' is an integer from 14 to 18, y is an integer from 22 to 26, y' is an integer from 58 to 62, z is an integer from 68 to 72, M is an increased binding energy hydrogen compound, the monomers may be arranged in any order, and the hydrogen content  $(H_x)_q(H_{x'})_r(H_y)_s(H_{y'})_t(H_z)_u$  of the compound comprises at least one increased binding energy hydrogen species.

The polymer compound may have the formula comprising one or more monomers in any order selected from the group comprising  $[KHKOH]_p [KH_5KOH]_q [KH KHCO_3]_r [KHCO_3]_s [K_2CO_3]_t$ , wherein p, q, r, s, and t are integers, the compound contains at least one H, and the hydrogen content H of the compound comprises at least one increased binding energy hydrogen.

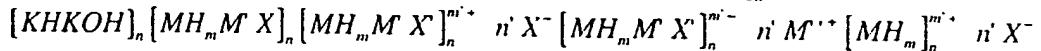
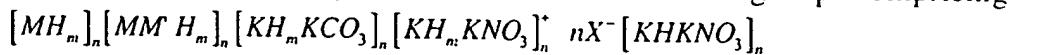
The polymer compound may have the formula comprising one or more monomers in any order selected from the group comprising  $[MH_m]_n [MM' H_m]_n [KH_m KCO_3]_n [KH_m KNO_3]_n nX^- [KHKNO_3]_n$   
 $[KHKOH]_n [MH_m M' X]_n [MH_m M' X]^{m'+} n' X^- [MH_m M' X]_n^{m'-} n' M'^+ [MH_m]_n^{m'+} n' X^-$   
 $[MH_m]_n^{m'-} n' M^+ M^+ H_{16}^- [KHKOH]_p [KH_5KOH]_q [KH KHCO_3]_r [KHCO_3]_s [K_2CO_3]_t$ , wherein  
 n, n', m, m', p, q, r, s, and t are integers, M, M' and M'' are each an alkali or alkaline earth, organic, organometallic, inorganic, or ammonium cation, X and X' are a singly or doubly negative charged anion, the compound contains at least one H, and the hydrogen content H of the compound comprises at least one increased binding energy hydrogen species.

The polymer compound may have the formula comprising one or more monomers in any order selected from the group comprising  $[MH_m]_n [MM' H_m]_n [KH_m KCO_3]_n [KH_m KNO_3]_n nX^- [KHKNO_3]_n$   
 $[KHKOH]_n [MH_m M' X]_n [MH_m M' X]^{m'+} n' X^- [MH_m M' X]_n^{m'-} n' M'^+ [MH_m]_n^{m'+} n' X^-$   
 $[MH_m]_n^{m'-} n' M^+ M^+ H_{16}^- [KHKOH]_p [KH_5KOH]_q [KH KHCO_3]_r [KHCO_3]_s [K_2CO_3]_t$   
 $M'''(H_{10})_q (H_{16})_r (H_{24})_s (H_{60})_t (H_{70})_u$ , wherein n, n', m, m', p, q, r, s, t, q', r', s', t', and u are each an integer, M, M' and M'' are each an alkali or alkaline earth, organic, organometallic, inorganic, or ammonium cation, M''' is other element, X and X' are a singly or doubly negative charged anion, the compound contains at least one H, and the hydrogen content H of the compound comprises at least one increased binding energy hydrogen species.

The polymer compound may have the formula comprising one or more monomers in any order selected from the group comprising  $[MH_m]_n [MM' H_m]_n [KH_m KCO_3]_n [KH_m KNO_3]_n nX^- [KHKNO_3]_n$   
 $[KHKOH]_n [MH_m M' X]_n [MH_m M' X]^{m'+} n' X^- [MH_m M' X]_n^{m'-} n' M'^+ [MH_m]_n^{m'+} n' X^-$   
 $[MH_m]_n^{m'-} n' M^+ M^+ H_{16}^- [KHKOH]_p [KH_5KOH]_q [KH KHCO_3]_r [KHCO_3]_s [K_2CO_3]_t$   
 $M'''(H_{10})_q (H_{16})_r (H_{24})_s (H_{60})_t (H_{70})_u$ , wherein n, n', m, m', p, q, r, s, t, q', r', s', t', and u are each an integer, M, M' and M'' are each an alkali or alkaline

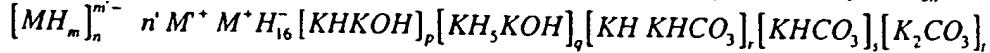
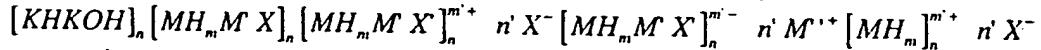
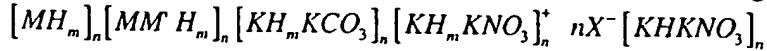
earth, organic, organometallic, inorganic, or ammonium cation, M''' is an increased binding energy hydrogen compound, X and X' are a singly or doubly negative charged anion, the compound contains at least one H, and the hydrogen content H of the compound comprises at least one increased binding energy hydrogen species.

The polymer compound may have the formula comprising one or more monomers in any order selected from the group comprising



[10]  $[MH_m]_n^{m'-} n'M''^+ M''^+ H_{16}^- [KHKOH]_p [KH_5KOH]_q [KH KHCO_3]_r [KHCO_3]_s [K_2CO_3]_t$   
 $M'''(H_x)_q (H_x)_r (H_y)_s (H_y)_t (H_z)_u$  wherein n, n', m, m', p, q, r, s, t, q', r', s', t', and u are each an integer, x is an integer from 8 to 12, x' is an integer from 14 to 18, y is an integer from 22 to 26, y' is an integer from 58 to 62, z is an integer from 68 to 72, M, M' and M'' are each an alkali or alkaline earth, organic, organometallic, inorganic, or ammonium cation, M''' is other element, X and X' are a singly or doubly negative charged anion, the compound contains at least one H, and the hydrogen content H of the compound comprises at least one increased binding energy hydrogen species.

[20] The polymer compound may have the formula comprising one or more monomers in any order selected from the group comprising



[25]  $M'''(H_x)_q (H_x)_r (H_y)_s (H_y)_t (H_z)_u$  wherein n, n', m, m', p, q, r, s, t, q', r', s', t', and u are each an integer, x is an integer from 8 to 12, x' is an integer from 14 to 18, y is an integer from 22 to 26, y' is an integer from 58 to 62, z is an integer from 68 to 72, M, M' and M'' are each an alkali or alkaline earth, organic, organometallic, inorganic, or ammonium cation, M''' is an increased binding energy hydrogen compound, X and X' are a singly or doubly negative charged anion, the compound contains at least one H, and the hydrogen content H of the compound comprises at least one increased binding energy hydrogen species.

[30] The polymer compound may have the formula comprising one or more monomers in any order selected from the group comprising

[35] The polymer compound may have the formula comprising one or more monomers in any order selected from the group comprising

- [ $MH_m$ ]<sub>n</sub>[ $MM' H_m$ ]<sub>n</sub>[ $KH_m KCO_3$ ]<sub>n</sub>[ $KH_m KNO_3$ ]<sub>n</sub> $nX^- [KHKNO_3]$ <sub>n</sub>  
 [ $KHKOH$ ]<sub>n</sub>[ $MH_m M' X$ ]<sub>n</sub>[ $MH_m M' X'$ ]<sub>n</sub> $n' X^- [MH_m M' X']^{m'-} n' M^{++} [MH_m]^{m'+} n' X^-$   
 [ $MH_m$ ]<sub>n</sub> $n' M^+ M^+ H_{16}^- [KHKOH]_p [KH_5 KOH]_q [KH KHCO_3]_r [KHCO_3]_s [K_2 CO_3]_t$ ,  
 $M'''(H_x)_q(H_x)_r(H_y)_s(H_z)_u$  wherein n, n', m, m', p, q, r, s, t, q', r', s', t', and  
 5 u are each an integer, x is an integer from 8 to 12, x' is an integer from 14 to 18, y is an integer from 22 to 26, y' is an integer from 58 to 62, z is an integer from 68 to 72, M, M' and M'' are each a metal such as a transition metal, inner transition metal, tin, boron, or a rare earth, lanthanide, an alkali or alkaline earth, organic, organometallic, inorganic, or ammonium cation, M''' is other element, X and X' are a singly or doubly negative charged anion, the compound contains at least one H, and the hydrogen content H of the compound comprises at least one increased binding energy hydrogen species.

The polymer compound may have the formula comprising one or more monomers in any order selected from the group comprising  
 15 [ $MH_m$ ]<sub>n</sub>[ $MM' H_m$ ]<sub>n</sub>[ $KH_m KCO_3$ ]<sub>n</sub>[ $KH_m KNO_3$ ]<sub>n</sub> $nX^- [KHKNO_3]$ <sub>n</sub>  
 [ $KHKOH$ ]<sub>n</sub>[ $MH_m M' X$ ]<sub>n</sub>[ $MH_m M' X'$ ]<sub>n</sub> $n' X^- [MH_m M' X']^{m'-} n' M^{++} [MH_m]^{m'+} n' X^-$   
 [ $MH_m$ ]<sub>n</sub> $n' M^+ M^+ H_{16}^- [KHKOH]_p [KH_5 KOH]_q [KH KHCO_3]_r [KHCO_3]_s [K_2 CO_3]_t$ ,  
 $M'''(H_x)_q(H_x)_r(H_y)_s(H_z)_u$  wherein n, n', m, m', p, q, r, s, t, q', r', s', t', and  
 20 u are each an integer, x is an integer from 8 to 12, x' is an integer from 14 to 18, y is an integer from 22 to 26, y' is an integer from 58 to 62, z is an integer from 68 to 72, M, M' and M'' are each a metal such as a transition metal, inner transition metal, tin, boron, or a rare earth, lanthanide, an alkali or alkaline earth, organic, organometallic, inorganic, or ammonium cation, M''' is an increased binding energy hydrogen compound, X and X' are a singly or doubly negative charged anion, the compound contains at least one H, and the hydrogen content H of the compound comprises at least one increased binding energy hydrogen species.

The polymer compound may have the formula  $Si_x H_y (H_{16})_z$  wherein x is an integer, y is an integer from  $2x+2$  to  $4x$ , z is an integer, and the hydrogen content H of the compound comprises at least one increased binding energy hydrogen species.

The polymers described herein can be formulated to any desired molecular weight for the particular application. Examples of suitable number average molecular weights include from about 3 up to about

$1 \times 10^7$ . Polymers based primarily on hydrinos usually have a molecular weight towards the lower molecular weight range, while polymers containing heavy elements such as silicon usually have higher molecular weights.

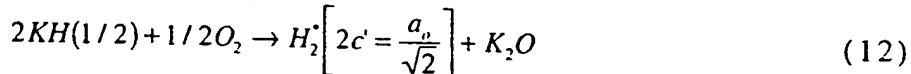
- 5 Examples of singly negative charged anions of the increased binding energy hydrogen compounds disclosed herein include but are not limited to halogen ions, hydroxide ion, dihydrogen phosphate ion, hydrogen carbonate ion, and nitrate ion. Examples of doubly negative charged anions of the increased binding energy hydrogen compounds disclosed  
10 herein include but are not limited to carbonate ion, oxides, phosphates, hydrogen phosphates, and sulfate ion.

Applications of the compounds include use in batteries, fuel cells, cutting materials, light weight high strength structural materials and synthetic fibers, corrosion resistant coatings, heat resistant coatings,  
15 xerographic compounds, proton source, photoluminescent compounds, phosphors for lighting, photoconductors, photovoltaics, chemiluminescent compounds, fluorescent compounds, optical coatings, optical filters, extreme ultraviolet laser media, fiber optic cables, magnets and magnetic computer storage media, superconductors, and etching agents, masking  
20 agents, agents to purify silicon, dopants in semiconductor fabrication, cathodes for thermionic generators, fuels, explosives, and propellants. Increased binding energy hydrogen compounds are useful in chemical synthetic processing methods and refining methods. The increased binding energy hydrogen ion and the increased binding energy hydrogen  
25 molecular ion have application as the negative ion of the electrolyte of a high voltage electrolytic cell. The selectivity of increased binding energy hydrogen species in forming bonds with specific isotopes provides a means to purify desired isotopes of elements.

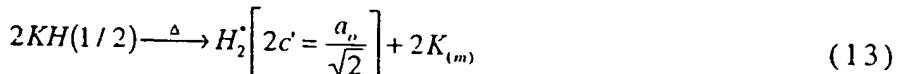
Alkali halides are known to be transparent to infrared radiation. A  
30 colored increased binding energy compound comprising an alkali or alkaline earth halide and at least one increased binding energy hydrogen species such as a hydrino hydride ion may be a medium to optically amplify infrared signals such as telecommunications signals. Two exemplary compounds are blue crystals of *KHI* and magenta crystals of  
35 *KHCl*. In another embodiment of a colored compound to amplify infrared light, F centers color the compound. F centers may be formed in an uncolored compound during the catalysis of hydrogen in the presence of

the compound. The uncolored compound which is colored by formation of F centers may comprise an alkaline or alkaline earth halide.

According to another aspect of the invention, dihydrinos, can be produced by reacting protons with hydrino hydride ions, or by the 5 thermal decomposition of hydrino hydride ions, or by the thermal or chemical decomposition of increased binding energy hydrogen compounds. For example, the hydrino hydride compound  $KII(1/p)$  or  $K(H(1/p))_2I$  may react with a source of oxygen such as oxygen gas or water to form 10 dihydrino and potassium oxide wherein the hydrino hydride ion has a relatively low binding energy such as  $H^-(1/2)$ .



Alternatively, the hydrino hydride compound may be heated to release dihydrino by thermal decomposition.



15 In both cases, the dihydrino product may be analyzed by gas chromatography.

A method is provided for preparing compounds comprising at least one increased binding energy hydride ion. Such compounds are hereinafter referred to as "hydrino hydride compounds". The method 20 comprises reacting atomic hydrogen with a catalyst having a net enthalpy of reaction of about  $\frac{m}{2} \cdot 27 \text{ eV}$ , where m is an integer greater than 1, preferably an integer less than 400, to produce an increased binding energy hydrogen atom having a binding energy of about  $\frac{13.6 \text{ eV}}{\left(\frac{1}{p}\right)^2}$  where p is an integer, preferably an integer from 2 to 200. A further product of 25 the catalysis is energy. The increased binding energy hydrogen atom can be reacted with an electron source, to produce an increased binding energy hydride ion. The increased binding energy hydride ion can be reacted with one or more cations to produce a compound comprising at least one increased binding energy hydride ion.

30 The invention is also directed to a reactor for producing increased binding energy hydrogen compounds of the invention, such as hydrino hydride compounds. A further product of the catalysis is energy. Such a

reactor is hereinafter referred to as a "hydrino hydride reactor". The hydrino hydride reactor comprises a cell for making hydrinos and an electron source. The reactor produces hydride ions having the binding energy of Eq. (10). The cell for making hydrinos may take the form of an electrolytic cell, a gas cell, a gas discharge cell, or a plasma torch cell, for example. Each of these cells comprises: a source of atomic hydrogen; at least one of a solid, molten, liquid, or gaseous catalyst for making hydrinos; and a vessel for reacting hydrogen and the catalyst for making hydrinos. As used herein and as contemplated by the subject invention, the term "hydrogen", unless specified otherwise, includes not only protium ( $^1H$ ), but also deuterium ( $^2H$ ) and tritium ( $^3H$ ). Electrons from the electron source contact the hydrinos and react to form hydrino hydride ions.

The reactors described herein as "hydrino hydride reactors" are capable of producing not only hydrino hydride ions and compounds, but also the other increased binding energy hydrogen compounds of the present invention. Hence, the designation "hydrino hydride reactors" should not be understood as being limiting with respect to the nature of the increased binding energy hydrogen compound produced.

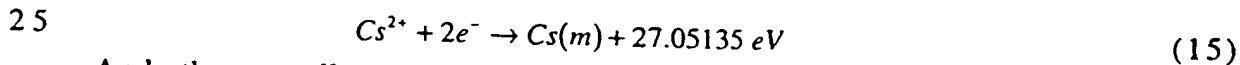
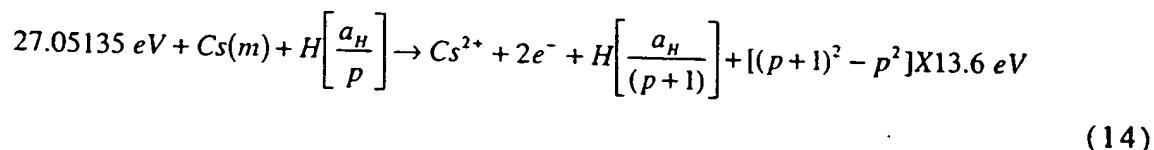
According to one aspect of the present invention, novel compounds are formed from hydrino hydride ions and cations. In the electrolytic cell, the cation may be either an oxidized species of the material of the cell cathode or anode, a cation of an added reductant, or a cation of the electrolyte (such as a cation comprising the catalyst). The cation of the electrolyte may be a cation of the catalyst. In the gas cell, the cation can be an oxidized species of the material of the cell, a cation comprising the molecular hydrogen dissociation material which produces atomic hydrogen, a cation comprising an added reductant, or a cation present in the cell (such as a cation comprising the catalyst). In the discharge cell, the cation can be an oxidized species of the material of the cathode or anode, a cation of an added reductant, or a cation present in the cell (such as a cation comprising the catalyst). In the plasma torch cell, the cation can be either an oxidized species of the material of the cell, a cation of an added reductant, or a cation present in the cell (such as a cation comprising the catalyst).

Catalysts

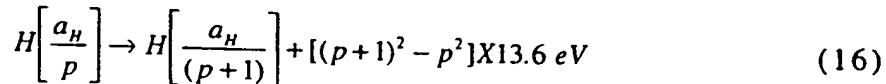
A catalyst of the present invention can be an increased binding energy hydrogen compound having a net enthalpy of reaction of about  $\frac{m}{2} \cdot 27 \text{ eV}$ , where  $m$  is an integer greater than 1, preferably an integer less than 400, to produce an increased binding energy hydrogen atom having a binding energy of about  $\frac{13.6 \text{ eV}}{\left(\frac{1}{p}\right)^2}$  where  $p$  is an integer, preferably an integer from 2 to 200.

 $t$  Electron Transfer (One Species)

In another embodiment, a catalytic system is provided by the ionization of  $t$  electrons from a participating species such as an atom, an ion, a molecule, and an ionic or molecular compound to a continuum energy level such that the sum of the ionization energies of the  $t$  electrons is approximately  $m \times 27.2 \text{ eV}$  where  $m$  is an integer. One such catalytic system involves cesium. The first and second ionization energies of cesium are 3.89390 eV and 23.15745 eV, respectively [David R. Linde, CRC Handbook of Chemistry and Physics, 74 th Edition, CRC Press, Boca Raton, Florida, (1993), p. 10-207]. The double ionization ( $t=2$ ) reaction of Cs to  $\text{Cs}^{2+}$ , then, has a net enthalpy of reaction of 27.05135 eV, which is equivalent to  $m=1$  in Eq. (2).



And, the overall reaction is



Thermal energies may broaden the enthalpy of reaction. The relationship between kinetic energy and temperature is given by

$$E_{kinetic} = \frac{3}{2} kT \quad (17)$$

For a temperature of 1200 K, the thermal energy is 0.16 eV, and the net enthalpy of reaction provided by cesium metal is 27.21 eV which is

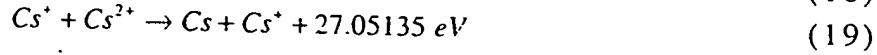
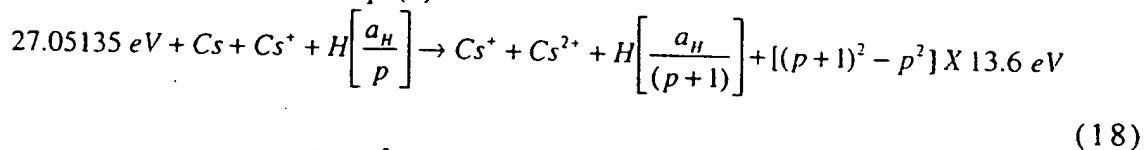
an exact match to the desired energy.

Hydrogen catalysts capable of providing a net enthalpy of reaction of approximately  $m \times 27.2 \text{ eV}$  where  $m$  is an integer to produce hydrino whereby  $i$  electrons are ionized from an atom or ion are given *infra*. A further product of the catalysis is energy. The atoms or ions given in the first column are ionized to provide the net enthalpy of reaction of  $m \times 27.2 \text{ eV}$  given in the tenth column where  $m$  is given in the eleventh column. The electrons which are ionized are given with the ionization potential (also called ionization energy or binding energy). The ionization potential of the  $n$ th electron of the atom or ion is designated by  $IP_n$  and is given by David R. Linde, CRC Handbook of Chemistry and Physics, 78 th Edition, CRC Press, Boca Raton, Florida, (1997), p. 10-214 to 10-216 which is herein incorporated by reference. That is for example,  $Cs + 3.89390 \text{ eV} \rightarrow Cs^+ + e^-$  and  $Cs^+ + 23.15745 \text{ eV} \rightarrow Cs^{2+} + e^-$ . The first ionization potential,  $IP_1 = 3.89390 \text{ eV}$ , and the second ionization potential,  $IP_2 = 23.15745 \text{ eV}$ , are given in the second and third columns, respectively. The net enthalpy of reaction for the double ionization of  $Cs$  is  $27.05135 \text{ eV}$  as given in the tenth column, and  $m=1$  in Eq. (2) as given in the eleventh column.

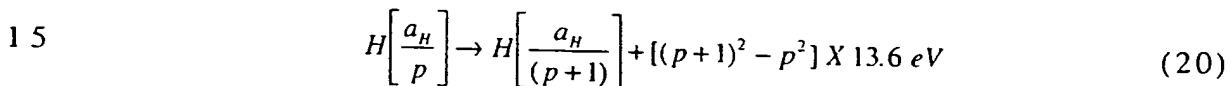
Catalyst	IP1	IP2	IP3	IP4	IP5	IP6	IP7	IP8	Enthalpy m
Li	5.39172	75.6402							81.032 3
Be	9.32263	18.2112							27.534 1
K	4.34066	31.63	45.806						81.777 3
Ca	6.11316	11.8717	50.9131	67.27					136.17 5
Ti	6.8282	13.5755	27.4917	43.267	99.3				190.46 7
V	6.7463	14.66	29.311	46.709	65.2817				162.71 6
Cr	6.76664	16.4857	30.96						54.212 2
Mn	7.43402	15.64	33.668	51.2					107.94 4
Fe	7.9024	16.1878	30.652						54.742 2
Fe	7.9024	16.1878	30.652	54.8					109.54 4
Co	7.881	17.083	33.5	51.3					109.76 4
Co	7.881	17.083	33.5	51.3	79.5				189.26 7
Ni	7.6398	18.1688	35.19	54.9	76.06				191.96 7
Ni	7.6398	18.1688	35.19	54.9	76.06	108			299.96 11
Cu	7.72638	20.2924							28.019 1
Zn	9.39405	17.9644							27.358 1
Zn	9.39405	17.9644	39.723	59.4	82.6	108	134	174	625.08 23
As	9.8152	18.633	28.351	50.13	62.63	127.6			297.16 11
Se	9.75238	21.19	30.8204	42.945	68.3	81.7	155.4		410.11 15
Kr	13.9996	24.3599	36.95	52.5	64.7	78.5			271.01 10
Kr	13.9996	24.3599	36.95	52.5	64.7	78.5	111		382.01 14
Rb	4.17713	27.285	40	52.6	71	84.4	99.2		378.66 14
Rb	4.17713	27.285	40	52.6	71	84.4	99.2	136	514.66 19
Sr	5.69484	11.0301	42.89	57	71.6				188.21 7
Nb	6.75885	14.32	25.04	38.3	50.55				134.97 5
Mo	7.09243	16.16	27.13	46.4	54.49	68.8276			151.27 8
Mo	7.09243	16.16	27.13	46.4	54.49	68.8276	125.664	143.6	489.36 18
Pd	8.3369	19.43							27.767 1
Sn	7.34381	14.6323	30.5026	40.735	72.28				165.49 6
Te	9.0096	18.6							27.61 1
Te	9.0096	18.6	27.96						55.57 2
Cs	3.8939	23.1575							27.051 1
Ce	5.5387	10.85	20.198	36.758	65.55				138.89 5
Ce	5.5387	10.85	20.198	36.758	65.55	77.6			216.49 8
Pr	5.464	10.55	21.624	38.98	57.53				134.15 5
Sm	5.6437	11.07	23.4	41.4					81.514 3
Gd	6.15	12.09	20.63	44					82.87 3
Dy	5.9389	11.67	22.8	41.47					81.879 3
Pb	7.41666	15.0322	31.9373						54.386 2
Pt	8.9587	18.563							27.522 1
He+		54.4178							54.418 2
Rb+		27.285							27.285 1
Fe3+			54.8						54.8 2
Mo2+			27.13						27.13 1
Mo4+				54.49					54.49 2
In3+				54					54 2

Two Electron Transfer(Two Species); m=1 in Eq. (2)

In another embodiment, a catalytic system transfers an electron to a vacuum energy level from each of two species selected from the set of atom, ion, or molecule such that the sum of the ionization energies of the 5 participating atoms, ions, and/or molecules is approximately  $m \times 27.2 \text{ eV}$  where  $m$  is an integer. One such catalytic system involves cesium. The first and second ionization energies of cesium are  $3.89390 \text{ eV}$  and  $23.15745 \text{ eV}$ , respectively. The combination of reactions  $Cs$  to  $Cs^+$  and  $Cs^+$  to  $Cs^{2+}$ , then, has a net enthalpy of reaction of  $27.05135 \text{ eV}$ , which is 10 equivalent to  $m=1$  in Eq. (2).



The overall reaction is



Hydrogen catalysts capable of providing a net enthalpy of reaction of approximately  $27.2 \text{ eV}$  to produce hydrino whereby each of two atoms or ions are oxidized are given *infra*. The atoms or ions in the first and 20 fourth columns are oxidized to provide the net enthalpy of reaction. The number in the column following the atom or ion, ( $n$ ), is the  $n$ th ionization energy of the atom or ion. That is for example,  $Cs + 3.89390 \text{ eV} \rightarrow Cs^+ + e^-$  and  $Cs^+ + 23.15745 \text{ eV} \rightarrow Cs^{2+} + e^-$ . The net enthalpy of reaction for oxidation of  $Cs$  and  $Cs^+$  is  $27.05135 \text{ eV}$  as given in the seventh column.

First Atom or Ion Oxidized	n th Ionization	n th Ionization Energy (eV)	Second Atom or Ion Oxidized	n th Ionization	n th Ionization Energy (eV)	Net Enthalpy of Reaction of Catalyst (eV)
Li	1	5.39172	Cs <sup>+</sup>	2	23.15745	28.54917
Na	1	5.13908	Cs <sup>+</sup>	2	23.15745	28.29653
K	1	4.34066	Cs <sup>+</sup>	2	23.15745	27.49811
Rb	1	4.17713	Cs <sup>+</sup>	2	23.15745	27.33458
Cs	1	3.89390	Cs <sup>+</sup>	2	23.15745	27.05135
Ba	1	5.21170	Cs <sup>+</sup>	2	23.15745	28.36915
Fr	1	4.0727	Cs <sup>+</sup>	2	23.15745	27.23015
Ra	1	5.27892	Cs <sup>+</sup>	2	23.15745	28.43637
Ac	1	5.17	Cs <sup>+</sup>	2	23.15745	28.32745
O	1	13.61806	O	1	13.61806	27.23612
H	1	13.59844	O	1	13.61806	27.2165
H	1	13.59844	H	1	13.59844	27.19688

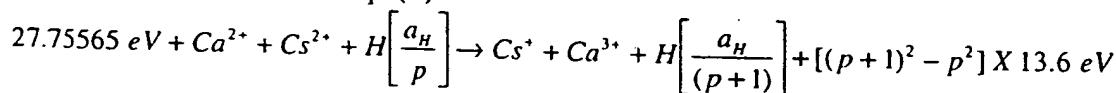
#### Single Electron Transfer (Multiple Species)

A catalysts is provided by the transfer of an electron between participating species including atoms, ions, molecules, and 5 ionic and molecular compounds. In one embodiment, the transfer of an electron from one species to another species provides a net enthalpy of reaction whereby the sum of the ionization energy of the electron donating species minus the ionization energy or electron affinity of the electron accepting species equals approximately  $m \times 27.2 \text{ eV}$  where  $m$  is an integer.

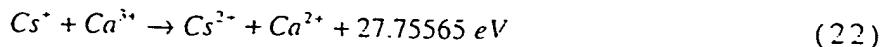
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#### Single Electron Transfer (Two Species); $m=1$ in Eq. (2)

One such catalytic system involves calcium and cesium. The third ionization energy of calcium is  $50.9131 \text{ eV}$ ; and  $\text{Cs}^{2+}$  releases  $23.15745 \text{ eV}$  when it is reduced to  $\text{Cs}^+$ . The combination of reactions  $\text{Ca}^{2+}$  to  $\text{Ca}^{3+}$  and  $\text{Cs}^{2+}$  to  $\text{Cs}^+$ , then, has a net enthalpy of reaction of  $27.75565 \text{ eV}$ , which is equivalent to  $m=1$  in Eq. (2).



(21)



The overall reaction is

$$H\left[\frac{a_H}{p}\right] \rightarrow H\left[\frac{a_H}{(p+1)}\right] + [(p+1)^2 - p^2] \times 13.6 \text{ eV} \quad (23)$$

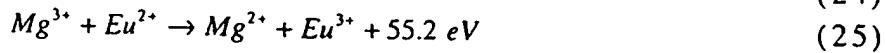
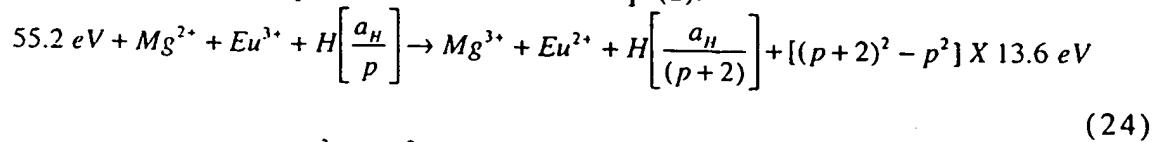
Hydrogen catalysts capable of providing a net enthalpy of reaction of approximately 27.2 eV to produce hydrino whereby an electron is transferred from one species to a second species are given *infra*. The atom or ion in the first column is oxidized, and the atom or ion in the fourth column is reduced to provide the net enthalpy of reaction. The number in the column following the atom or ion, (n), is the nth ionization energy of the atom or ion. That is for example,  $Ca^{2+} + 50.9131 \text{ eV} \rightarrow Ca^{3+} + e^-$  and  $Cs^{2+} + e^- \rightarrow Cs^+ + 21.15745 \text{ eV}$ . The net enthalpy of reaction for an electron transfer from  $Ca^{2+}$  to  $Cs^{2+}$  is 27.76 eV as given in the seventh column.

Atom or Ion Oxidized	n th Ionization	n th Ionization Energy (eV)	Atom or Ion Reduced	n th Ionization	n th Ionization Energy (eV)	Net Enthalpy of Reaction of Catalyst (eV)
$Ca^{2+}$	3	50.9131	$Cs^{2+}$	2	23.15745	27.75565
$Mn^{3+}$	4	51.2	$Cs^{2+}$	2	23.15745	28.04
$As^{3+}$	4	50.13	$Cs^{2+}$	2	23.15745	26.97255
$Nb^{4+}$	5	50.55	$Cs^{2+}$	2	23.15745	27.39255
$La^{3+}$	4	49.95	$Cs^{2+}$	2	23.15745	26.79255

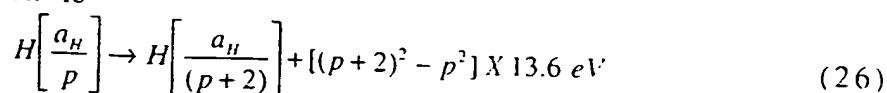
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#### Single Electron Transfer (Two Species); m = 2 in Eq. (2)

One such catalytic system involves magnesium and europium. The third ionization energy of magnesium is 80.143 eV, and the second ionization energy of europium is 24.9 eV. The combination of reactions  $Mg^{2+}$  to  $Mg^{3+}$  and  $Eu^{3+}$  to  $Eu^{2+}$ , then, has a net enthalpy of reaction of 55.2 eV, which is equivalent to  $m=2$  in Eq. (2).



The overall reaction is

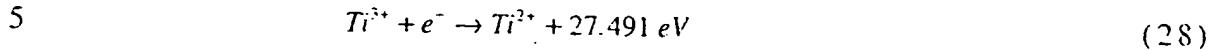
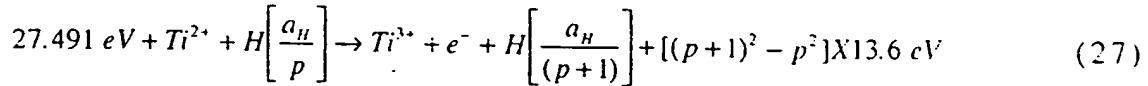


Hydrogen catalysts capable of providing a net enthalpy of reaction of approximately 54.4 eV to produce hydrino whereby an electron is transferred from one ion to another are given *infra*. The atoms or ions in the first column are oxidized while the atoms or ions in the fourth column are reduced to provide the net enthalpy of reaction. The number in the column following the atom or ion, (n), is the nth ionization energy of the atom or ion. That is for example,  $Mg^{2+} + 80.143 \text{ eV} \rightarrow Mg^{3+} + e^-$  and  $Eu^{3+} + e^- \rightarrow Eu^{2+} + 24.9 \text{ eV}$ . The net enthalpy of reaction for oxidation of  $Mg^{2+}$  and the reduction of  $Eu^{3+}$  is 55.2 eV as given in the seventh column.

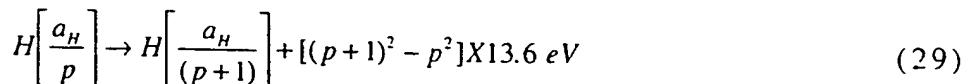
Atom or Ion Oxidized	n th Ionization	n th Ionization Energy (eV)	Atom or Ion Reduced	n th Ionization	n th Ionization Energy (eV)	Net Enthalpy of Reaction of Catalyst (eV)
$Mg^{2+}$	3	80.143	$Sc^{3+}$	2	27.76	55.38
$Mg^{2+}$	3	80.143	$Nb^{3+}$	2	25.04	54.7
$Mg^{2+}$	3	80.143	$Sb^{3+}$	2	25.3	54.8
$Mg^{2+}$	3	80.143	$Eu^{3+}$	2	24.9	55.2
$Mg^{2+}$	3	80.143	$Yb^{3+}$	2	25.03	55.1
$Dy^{3+}$	4	41.50	$Bi^{3+}$	2	25.56	54.58

Titanium hydrino hydride may be an effective catalyst wherein  $Ti^{2+}$  is the active species. Furthermore, titanium hydrino hydride is volatile and may serve as a gaseous transition catalyst. Titanium is typically in a 4+ oxidation state. Increased binding energy hydrogen species such as hydrino hydride ions may stabilize the 2+ oxidation state. Exemplary titanium (II) hydrino hydride compounds are  $TiH(1/p)_2$ , and  $TiH(1/p)_2 \left( H_2 \left[ 2c' = \frac{\sqrt{2}a_0}{p} \right] \right)$  where p is an integer greater than 1, preferably from 2 to 200. Titanium (II) is a catalyst because the third ionization energy is 27.49 eV, m=1 in Eq. (2). Thus, the catalysis cascade for the p th

cycle is represented by

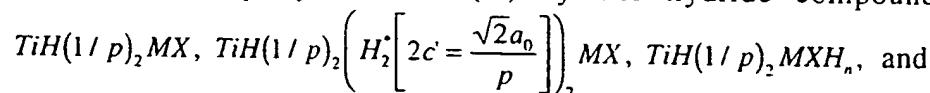


And, the overall reaction is



10 where  $p$  is an integer greater than 1, preferably from 2 to 200.

Titanium hydrino hydride may be combined with another element to increase the effectiveness of the catalyst when  $Ti^{2+}$  is the active species. Exemplary titanium (II) hydrino hydride compounds are

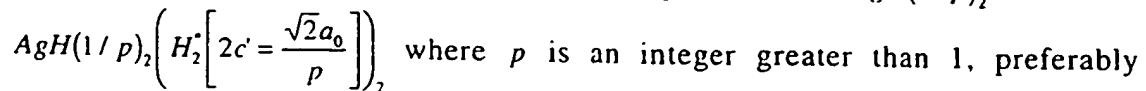


15  $TiH(1/p)_2 \left(H_2 \left[2c' = \frac{\sqrt{2}a_0}{p}\right]\right)_2 MXH_n$  where  $p$  is an integer greater than 1,

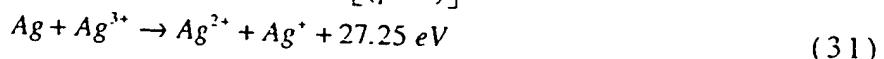
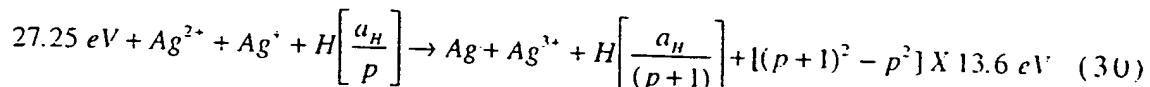
preferably from 2 to 200,  $n$  is an integer, preferably from 1 to 100,  $M$  is an alkaline, alkaline earth, transition metal, inner transition metal, or rare earth cation,  $X$  is an anion such as halogen ions, hydroxide ion, hydrogen carbonate ion, nitrate ion, carbonate ion, oxides, phosphates, hydrogen phosphates, and sulfate ion, and  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H$ . Preferably, the more effective titanium hydrino hydride catalyst is  $TiH(1/p)_2 NiO$  or  $TiH(1/p)_2 NiOH_2$ .

20 Silver hydrino hydride may be an effective catalyst wherein  $Ag^{2+}$  and  $Ag^+$  are the active species. Furthermore, silver hydrino hydride may be volatile and may serve as a gaseous transition catalyst. Silver is typically in a 1+ oxidation state. Increased binding energy hydrogen species such as hydrino hydride ions may stabilize the 2+ oxidation state.

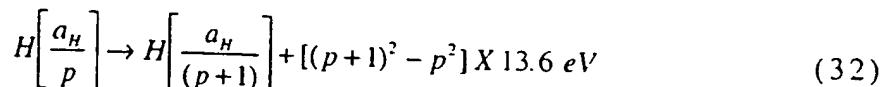
25 Exemplary silver (II) hydrino hydride compounds are  $AgH(1/p)_2$  and



from 2 to 200. Silver may be a catalytic system because the third ionization energy of silver is 34.83 eV; and  $Ag^+$  releases 7.58 eV when it is reduced to  $Ag$ . The combination of reactions  $Ag^{2+}$  to  $Ag^{3+}$  and  $Ag^+$  to  $Ag$ , then, has a net enthalpy of reaction of 27.25 eV, which is equivalent to  $m=1$  in Eq. (2).

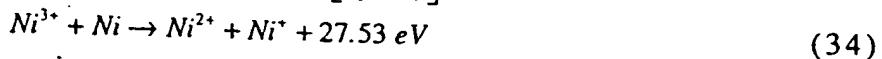
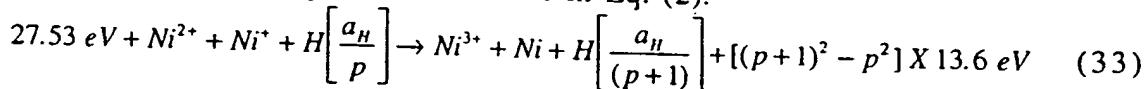


The overall reaction is

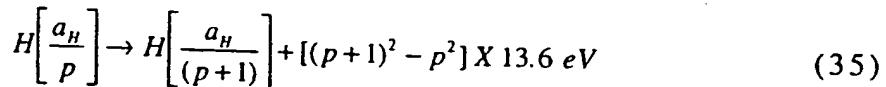


where  $p$  is an integer greater than 1, preferably from 2 to 200.

Nickel hydrino hydride may be an effective catalyst wherein  $Ni^{2+}$  and  $Ni^+$  are the active species. Furthermore, nickel hydrino hydride may be volatile and may serve as a gaseous transition catalyst. Nickel is typically in a 2+ oxidation state. Increased binding energy hydrogen species such as hydrino hydride ions may stabilize the 1+ oxidation state. An exemplary nickel (I) hydrino hydride compounds is  $NiH(1/p)$  where  $p$  is an integer greater than 1, preferably from 2 to 200. Nickel may be a catalytic system because the third ionization energy of nickel is 35.17 eV; and  $Ni^+$  releases 7.64 eV when it is reduced to  $Ni$ . The combination of reactions  $Ni^{2+}$  to  $Ni^{3+}$  and  $Ni^+$  to  $Ni$ , then, has a net enthalpy of reaction of 27.53 eV, which is equivalent to  $m=1$  in Eq. (2).



The overall reaction is



where  $p$  is an integer greater than 1, preferably from 2 to 200.

In the case that titanium, silver, or nickel metal is present in the cell and may be used as the dissociator to provide atomic hydrogen, the titanium, silver, or nickel hydrino hydride catalyst may have an accelerating catalytic rate wherein the product of catalysis, hydrino, may react with the titanium, silver, or nickel metal to produce further titanium, silver, or nickel hydrino hydride catalyst. A method to start the process is to add a catalyst such as  $KI$ ,  $K_2CO_3$ ,  $RbI$ , or  $Rb_2CO_3$  to the cell to

catalyze the initial formation of titanium, silver, or nickel hydrino hydride. Alternatively, some titanium, silver, or nickel hydrino hydride may be added to the cell or generated by reacting the titanium, silver, or nickel with a source of hydrogen atoms and catalyst such as an aqueous 5 solution of  $K_2CO_3$  and  $H_2O_2$  or an aqueous solution of  $Rb_2CO_3$  and  $H_2O_2$ .

An exemplary method to generate a hydrogen catalyst comprising hydrino hydride ions is to treat a titanium hydrogen dissociator with about 0.6 M  $K_2CO_3$ /10%  $H_2O_2$  to form the hydrogen catalyst  $TiH(1/p)_2$ .

Titanium hydrino hydride may form by a titanium peroxide intermediate. 10 The potassium ions present may catalyze the formation of hydrinos from hydrogen atoms formed by the decomposition of  $H_2O_2$ . The hydrinos may react with titanium to form titanium hydrino hydride. In the case of a gas cell hydrino hydride reactor with  $KI$  catalyst, for example, and hydrogen flow, potassium hydrino hydride may form with the loss of 15 iodine from the cell. Potassium hydrino hydride may react with titanium metal to form titanium hydrino hydride and potassium metal. In the case of a  $K_2CO_3$  catalyst, carbon dioxide and oxygen may be lost from the cell with the formation of potassium metal.

A further exemplary method to generate a hydrogen catalyst 20 comprising hydrino hydride ions is to treat a titanium hydrogen dissociator with about 0.6 M  $Rb_2CO_3$ /10%  $H_2O_2$  to form the hydrogen catalyst  $TiH(1/p)_2$ . Titanium hydrino hydride may form by a titanium peroxide intermediate. The rubidium ions present may catalyze the formation of hydrinos from hydrogen atoms formed by the decomposition 25 of  $H_2O_2$ . The hydrinos may react with titanium to form titanium hydrino hydride. In the case of a gas cell hydrino hydride reactor with  $RbI$  catalyst, for example, and hydrogen flow, rubidium hydrino hydride may form with the loss of iodine from the cell. Rubidium hydrino hydride may react with titanium metal to form titanium hydrino hydride and 30 rubidium metal. In the case of a  $Rb_2CO_3$  catalyst, carbon dioxide and oxygen may be lost from the cell with the formation of rubidium metal.

Cesium metal may catalyze the formation of hydrinos from 35 hydrogen atoms. The hydrinos may react with titanium to form titanium hydrino hydride. For example, in the case of a gas cell hydrino hydride reactor with hydrogen flow and  $Cs(m)$  catalyst formed for the decomposition of  $Cs_2CO_3$ , cesium hydrino hydride may form with the loss of carbonate from the cell as carbon dioxide and oxygen. Cesium hydrino

hydride may react with titanium metal to form titanium hydrino hydride and large amounts of cesium metal.

In another method to form hydrogen catalyst, titanium hydrino hydride, the formation of titanium hydrino hydride is initiated by the presence of a titanium compound such as a titanium halide (for example  $TiCl_4$ ),  $TiTe_2$ ,  $Ti_2(SO_4)_3$ , or  $TiS_2$  which may react with an increased binding energy hydrogen species to form titanium hydrino hydride in an operating gas cell hydrino hydride reactor. The increased binding energy hydrogen species may form in the operating hydrino hydride reactor.

Further examples of catalysts providing the catalytic reaction of Eqs. (3-5) is increased binding energy hydrogen compound  $KH_n$  where n is an integer from one to 100 and increased binding energy hydrogen compounds  $KH_nX$  where n is an integer from one to 100 H may be an increased binding energy hydrogen species and X is a compound such as  $KHSO_4$ ,  $KHI$ ,  $KHCO_3$ ,  $KHNO_3$ ,  $HNO_3$ ,  $KH_2PO_4$ , or  $KOH$ . In another embodiment, rubidium replaces potassium (e.g.  $RbHRbHCO_3$  or  $RbHRbOH$  are the hydrogen catalysts comprising an increased binding energy hydrogen species such as hydrino hydride ion). The hydrino hydride compounds which are catalysts may be gaseous catalyst by operating a gas cell hydrino hydride reactor at an elevated temperature.

A method to generate a hydrogen catalyst comprising a potassium or rubidium cation, an anion, and at least one increased binding energy hydrogen species such as a hydrino hydride ion is to treat a hydrogen dissociator such as nickel or titanium with an aqueous solution of about 0.6 molar salt comprising at least a potassium or rubidium cation and the anion and 10%  $H_2O_2$  to form the hydrogen catalyst. Alternatively, a first hydrogen catalyst having an anion is used in a hydrino hydride reactor such that the catalyst compound reacts with an increased binding energy hydrogen species to form a second hydrogen catalyst comprising a potassium or rubidium cation, an anion, and at least one increased binding energy hydrogen species such as a hydrino hydride ion. Exemplary anions are  $OH^-$ ,  $CO_3^{2-}$ ,  $HCO_3^-$ ,  $NO_3^-$ ,  $SO_4^{2-}$ ,  $HSO_4^-$ ,  $PO_4^{3-}$ ,  $HPO_4^{2-}$ , and  $H_2PO_4^-$ . For example, a method to generate a hydrogen catalyst comprising at least one increased binding energy hydrogen species such as a hydrino hydride ion is to treat a hydrogen dissociator such as nickel or titanium with about 0.6 M  $K_2CO_3$ /10%  $H_2O_2$  to form a hydrogen catalyst comprising

potassium and at least one increased binding energy hydrogen species such as  $KHKHCO_3$  or  $KHKOH$ .

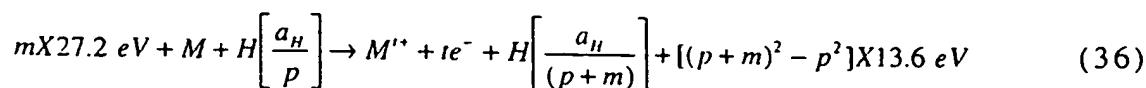
In an embodiment, the catalyst  $Rb^+$  according to Eqs. (6-8) may be formed from rubidium metal by ionization. The source of ionization may be UV light or a plasma. At least one of a source of UV light and a plasma may be provided by the catalysis of hydrogen with a one or more hydrogen catalysts such as potassium metal or  $K^+$  ions.

In an embodiment, the catalyst  $K^+/K^+$  according to Eqs. (3-5) may be formed from potassium metal by ionization. The source of ionization may be UV light or a plasma. At least one of a source of UV light and a plasma may be provided by the catalysis of hydrogen with a one or more hydrogen catalysts such as potassium metal or  $K^+$  ions.

In an embodiment, the catalyst  $Rb^+$  according to Eqs. (6-8) or the catalyst  $K^+/K^+$  according to Eqs. (3-5) may be formed by reaction of rubidium metal or potassium metal, respectively, with hydrogen to form the corresponding alkali hydride or by ionization at a hot filament which may also serve to dissociate molecular hydrogen to atomic hydrogen. The hot filament may be a refractory metal such as tungsten or molybdenum operated within a high temperature range such as 1000 to 2800 °C.

In an embodiment of the hydrino hydride reactor, a catalyst is selected such that a desired increased binding energy hydrogen species such as one selected from the group consisting of hydrino atom having a binding energy given by Eq. (1), a dihydrino molecule having a binding energy of about  $\frac{15.5}{\left(\frac{1}{P}\right)^2} eV$ , and hydrino hydride ion having a binding

energy given by Eq. (10) is formed. The catalyst may be selected such that it has a desired enthalpy of reaction of about  $m \times 27.2 eV$  where  $m$  is an integer to provide a selected catalysis of hydrogen. For example, the sum of the ionization energies of  $t$  electrons from an atom  $M$  to form  $M'^+$  is about  $m \times 27.2 eV$ . Thus, the catalysis cascade for the  $p$  th cycle is represented by



The overall reaction is

$$H\left[\frac{a_H}{p}\right] \rightarrow H\left[\frac{a_H}{(p+m)}\right] + [(p+m)^2 - p^2] \times 13.6 \text{ eV} \quad (38)$$

where  $p$  is an integer greater than 1, preferably from 2 to 200. The desired hydrino product may further react to form a desired increased binding energy hydrogen species or increased binding energy hydrogen compound.

It is believed that the rate of catalysis is increased as the net enthalpy of reaction is more closely matched to  $m \cdot 27.2 \text{ eV}$  where  $m$  is an integer. An embodiment of the hydrino hydride reactor for producing increased binding energy hydrogen compounds of the invention further comprises an electric or magnetic field source. The electric or magnetic field source may be adjustable to control the rate of catalysis. Adjustment of the electric or magnetic field provided by the electric or magnetic field source may alter the continuum energy level of a catalyst whereby one or more electrons are ionized to a continuum energy level to provide a net enthalpy of reaction of approximately  $m \times 27.2 \text{ eV}$ . The alteration of the continuum energy may cause the net enthalpy of reaction of the catalyst to more closely match  $m \cdot 27.2 \text{ eV}$ . Preferably, the electric field is within the range of  $0.01 - 10^6 \text{ V/m}$ , more preferably  $0.1 - 10^4 \text{ V/m}$ , and most preferably  $1 - 10^3 \text{ V/m}$ . Preferably, the magnetic flux is within the range of  $0.01 - 50 \text{ T}$ . A magnetic field may have a strong gradient. Preferably, the magnetic flux gradient is within the range of  $10^{-4} - 10^2 \text{ Tcm}^{-1}$  and more preferably  $10^{-3} - 1 \text{ Tcm}^{-1}$ .

For example, the cell may comprise a hot filament that dissociates molecular hydrogen to atomic hydrogen and may further heat a hydrogen dissociator such as transition elements and inner transition elements, iron, platinum, palladium, zirconium, vanadium, nickel, titanium, Sc, Cr, Mn, Co, Cu, Zn, Y, Nb, Mo, Tc, Ru, Rh, Ag, Cd, La, Hf, Ta, W, Re, Os, Ir, Au, Hg, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Vb, Lu, Th, Pa, U, activated charcoal (carbon), and intercalated Cs carbon (graphite). The filament may further supply an electric field in the cell of the reactor. The electric field may alter the continuum energy level of a catalyst whereby one or more electrons are ionized to a continuum energy level to provide a net enthalpy of reaction of approximately  $m \times 27.2 \text{ eV}$ . In another embodiment, an electric field is provided by electrodes charged by a variable voltage source. The rate of catalysis may be controlled by

controlling the applied voltage which determines the applied field which controls the catalysis rate by altering the continuum energy level.

- In another embodiment of the hydrino hydride reactor, the electric or magnetic field source ionizes an atom or ion to provide a catalyst having a net enthalpy of reaction of approximately  $m \times 27.2 \text{ eV}$ . For examples, potassium metal is ionized to  $K^+$ , or rubidium metal is ionized to  $Rb^+$  to provide the catalysts according to Eqs. (3-5) or Eqs. (6-8), respectively. The electric field source may be a hot filament whereby the hot filament may also dissociate molecular hydrogen to atomic hydrogen.
- 10 In the case that the hydrino hydride reactor comprises multiple catalysts that are selected to form one or more desired increased binding energy hydrogen species or increased binding energy hydrogen compounds, the electric or magnetic field provided by the electric or magnetic field source may be adjusted to preferentially increase the catalysis rate for one or more of the selected catalysts relative to one or more nonselected catalysts. Thus, the relative yield of one or more desired increased binding energy hydrogen species or increased binding energy hydrogen compounds may be adjusted.
- 15

- An further embodiment of the hydrino hydride reactor further comprises a source of thermal electrons. The source of electrons may reduce and thereby regenerate a catalyst whereby one or more electrons are ionized to a continuum energy level to provide a net enthalpy of reaction of approximately  $m \times 27.2 \text{ eV}$ . A hot filament may be a source of thermal electrons. The hot filament may further comprise one or more of the elements selected from the group of a hydrogen dissociator, a catalyst heater, a hydrogen dissociator heater, a cell heater, and a source of electric field.
- 20

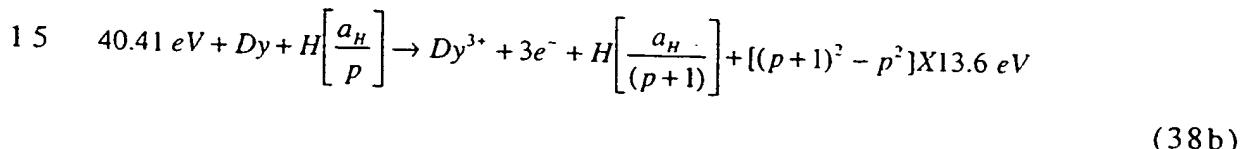
- In another embodiment of the catalyst of the present invention, hydrinos are formed by reacting an ordinary hydrogen atom with a catalyst having a net enthalpy of reaction of about
- 25

$$\frac{m}{2} \cdot 27.2 \text{ eV} \quad (38a)$$

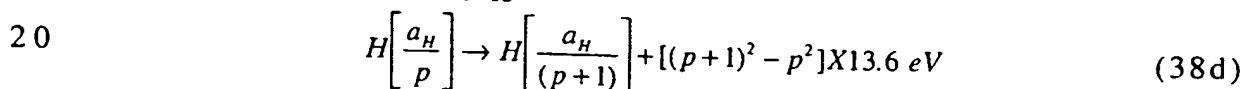
- 30 where  $m$  is an integer. It is believed that the rate of catalysis is increased as the net enthalpy of reaction is more closely matched to  $\frac{m}{2} \cdot 27.2 \text{ eV}$ . It has been found that catalysts having a net enthalpy of reaction within  $\pm 10\%$ , preferably  $\pm 5\%$ , of  $\frac{m}{2} \cdot 27.2 \text{ eV}$  are suitable for most applications.
- 35

*t* Electron Transfer (One Species)

In another embodiment, a catalytic system is provided by the ionization of *t* electrons from a participating species such as an atom, an ion, a molecule, and an ionic or molecular compound to a continuum energy level such that the sum of the ionization energies of the *t* electrons is approximately  $\frac{m}{2} \cdot 27.2 \text{ eV}$  where *m* is an integer. One such catalytic system involves dysprosium. The first, second, and third ionization energies of dysprosium are 5.9389 eV, 11.67 eV, and 22.8 eV, respectively [David R. Linde, CRC Handbook of Chemistry and Physics, 78 th Edition, CRC Press, Boca Raton, Florida, (1997), pp. 10-214-10-216]. The three ionization (*t*=3) reaction of Dy to  $Dy^{3+}$ , then, has a net enthalpy of reaction of 40.41 eV, which is equivalent to *m*=3 in Eq. 38a.



And, the overall reaction is



Hydrogen catalysts capable of providing a net enthalpy of reaction of approximately  $\frac{m}{2} \cdot 27.2 \text{ eV}$  where *m* is an integer to produce hydrino whereby *t* electrons are ionized from an atom or ion are given *infra*. The atoms or ions given in the first column are ionized to provide the net enthalpy of reaction of  $\frac{m}{2} \cdot 27.2 \text{ eV}$  given in the tenth column where *m* is given in the eleventh column. The electrons which are ionized are given with the ionization potential (also called ionization energy or binding energy). The ionization potential of the *n*th electron of the atom or ion is designated by  $IP_n$  and is given by David R. Linde, CRC Handbook of Chemistry and Physics, 78 th Edition, CRC Press, Boca Raton, Florida, (1997), pp. 10-214-10-216 which is herein incorporated by reference. That is for example,  $Dy + 5.9389 \text{ eV} \rightarrow Dy^+ + e^-$ ,  $Dy^+ + 11.67 \text{ eV} \rightarrow Dy^{2+} + e^-$  and  $Dy^{2+} + 22.8 \text{ eV} \rightarrow Dy^{3+} + e^-$ . The first ionization potential,  $IP_1 = 5.9389 \text{ eV}$ , the

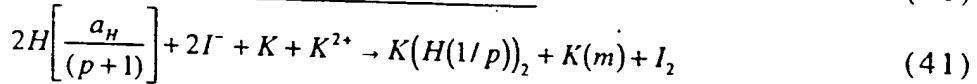
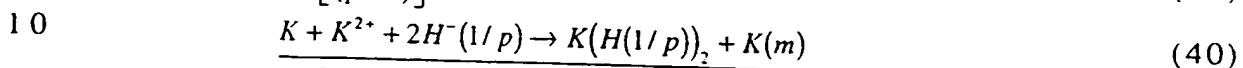
second ionization potential,  $IP_2 = 11.67 \text{ eV}$ , and the third ionization potential,  $IP_3 = 22.8 \text{ eV}$ , are given in the second, third, and fourth columns, respectively. The net enthalpy of reaction for the triple ionization of  $Dy$  is  $40.409 \text{ eV}$  as given in the tenth column, and  $m=3$  in Eq. (38a) as given in the eleventh column.

Catalyst	IP1	IP2	IP3	IP4	IP5	IP6	IP7	IP8	Enthalpy	m
Li	5.392	75.64							81.032	6
K	4.341	31.63	45.81						81.777	6
V	6.746	14.66	29.31	46.71	65.28				162.71	12
Cr	6.767	16.49	30.96						54.212	4
Se	9.752	21.19	30.82	42.95	68.3	81.7	155.4		410.11	30
Mo	7.092	16.16	27.13	46.4	54.49	68.83	125.7	143.6	489.36	36
Sn	7.344	14.63	30.5	40.74	72.28				165.49	12
Sm	5.644	11.07	23.4	41.4					81.514	6
Gd	6.15	12.09	20.63	44					82.87	6
Dy	5.939	11.67	22.8	41.47					81.879	6
Dy	5.939	11.67	22.8						40.409	3
Ho	6.022	11.8	22.84						40.662	3
Er	6.108	11.93	22.74						40.778	3
Lu	5.426	13.9	20.96						40.285	3

A process of the present invention is the formation of a metal such as potassium metal, rubidium metal, or cesium metal by the reduction of  $K^+$ ,  $Rb^+$ , or  $Cs^+$ , respectively, via the catalysis of hydrogen to form increased binding energy hydrogen compounds and the metal. Other metals such as lithium or sodium may be made by reacting potassium, rubidium, or cesium metal with a lithium or sodium compound, respectively. Techniques commonly used by those skilled in the art can be used in a similar manner to form and isolate other metals by reacting potassium, rubidium, or cesium metal with an alkali compound. The reaction may occur continuously in the hydrino hydride reactor. For example, a hydrogen catalyst such as  $K_2CO_3$  may be added to a gas cell hydrino hydride reactor containing an alkali compound such as  $Na_2CO_3$  or  $Li_2CO_3$ . Catalysis of hydrogen produces hydrino hydride compounds and potassium metal. Potassium metal is more active than lithium or sodium metal. Thus, the potassium metal reacts with  $Na_2CO_3$  or  $Li_2CO_3$  to form  $K_2CO_3$  and lithium or sodium metal, respectively. In one embodiment, the alkali compound that is not a hydrogen catalyst is present in a molar excess. In another embodiment, other elements or compounds of other elements present in the hydrino hydride reactor such as alkaline earth,

transition metal, rare earth, and precious metal compounds are reduced by an alkaline metal formed in the hydrino hydride reactor.

In the case that the catalyst is reduced to a metal during catalysis, the metal may accumulate in the reactor such as a gas cell hydrino 5 hydride reactor during operation. Hydrino hydride compounds having a cation in a high oxidation state may form. For example, the potassium catalysis reaction is given by Eqs. (3-5). A potassium metal forming reaction is:



Potassium metal may accumulate in the cell as  $I_2$  is pumped from the cell. The potassium metal may form an amalgam with the dissociator which inhibits hydrogen dissociation. Thus,  $I_2$  or  $HI$  may be supplied to the cell 15 to regenerate the catalyst  $KI$  and regenerate the dissociator. Alternatively, other oxidants such as water, oxygen, or an oxyanion may be supplied to the gas cell hydrino hydride reactor to react with the alkali metal.

Hydrogen polymers such as  $H_{16}$  may be synthesized from increased 20 binding energy hydrogen compounds by polymerization. Increased binding energy hydrogen compounds may be reacted with polymerizing agents such as oxidizing agents, reductants, or free radical generating agents to form polymers. Increased binding energy hydrogen species of increased binding energy hydrogen compounds may also be polymerized 25 by reacting with one or more of the polymerizing agents. Examples of suitable polymerize agents include nitric acid, hydro iodic acid, sulfuric acid, hydro fluoric acid, hydrochloric acid, potassium metal, and a mixture of base and hydrogen peroxide such as  $K_2CO_3/H_2O_2$ . Hydrogen polymers may also form during catalysis in the electrolytic cell, gas cell, gas 30 discharge cell, or plasma torch cell hydrino hydride reactor. In one embodiment, hydrogen polymers such as  $H_{16}$  may be synthesized from hydrogen in a gas cell or gas discharge cell wherein the source of catalyst is potassium metal. Hydrogen polymer compounds may be purified from the reaction mixture by the methods given in the Purification of

Increased Binding Energy Hydrogen Compounds section of my previous PCT Patent Application, PCT US98/14029 filed on July 7, 1998, which is incorporated herein by reference.

Hydrogen polymers such as  $H_{16}$  may also be synthesized from increased binding energy hydrogen compounds by polymerization at high temperature. In one embodiment, an increased binding energy hydrogen compound such as potassium hydrino hydride or titanium hydrino hydride is formed as an intermediate that is polymerized at high temperature in a high temperature reactor. Examples of suitable temperatures are within the range of about 500 °C to about 2800 °C. For example, if the increased binding energy hydrogen compounds are formed in a gas cell hydrino hydride reactor at one temperature, such a temperature within the range of about 350 °C to about 800 °C, the increased binding energy hydrogen compounds may polymerized in the gas cell hydrino hydrided reactor by elevating the reactor temperature to range within about 850 °C to about 2800 °C. In an embodiment, the polymerization may be catalyzed by a hot metal surface such as that of a hot refractory metal filament. For example, a gas cell hydrino hydride reactor may comprise a hot tungsten filament maintained at an elevated temperature such as a temperature within the range 1200 °C to 2800 °C wherein hydrogen catalysis occurs to form increased binding energy hydrogen species which polymerize on contact with the hot filament. Based on the disclosure herein, one skilled in the art will be able to select a suitable polymerization temperature to form the desired increased binding energy hydrogen polymer.

Hydrino hydride compounds have been found to be stable to electrolysis at a voltage that is substantially greater than that of ordinary compounds. Hydrino hydride compounds such as potassium hydrino hydride may be purified by electrolysis at a sufficiently high voltage that the anion of the catalyst is oxidized. In one embodiment, the reaction products of the hydrino hydride reactor are collected and run in a molten electrolytic cell such that the reduced cation of the catalyst such as potassium metal forms at the cathode, and the oxidized anion of the catalyst such as halogen gas (for example  $I_2$ ) forms at the anode. The electrolyzed catalyst products such as iodine gas and potassium metal are separated from the hydrino hydride compounds that are stable to

electrolysis. Methods of separation such as distillation and phase separation techniques commonly used by those skilled in the art can be used in a similar manner to isolate hydrino hydride compounds. For example, iodine can be removed at low temperatures as a gas, and 5 potassium metal can be removed with the cathode onto which it electroplates.

A method of isotope separation comprises the step of reacting an element or compound having an isotopic mixture containing the desired element with an increased binding energy hydrogen species in atomic 10 percent shortage based on the stoichiometric amount to fully react with or bond to the desired isotope. The increased binding energy hydrogen species is selected such that the bond energy of the reaction product is dependent on the isotope of the desired element. Thus, an increased binding energy species can be selected such that the predominant 15 reaction product contains at least one increased binding energy hydrogen species bound to the desired isotope. The compound comprising at least one increased binding energy hydrogen species and the desired isotope can be separated from the reaction mixture. The increased binding energy hydrogen species may be separated from the desired isotope to 20 obtain the desired isotope. The recovered isotope may be reacted with the increased binding energy hydrogen species and these steps may be repeated to obtain a desired level of enrichment. The use of the term "isotope" in this context includes an individual element as well as compounds containing the desired elemental isotope.

Another method of isotope separation comprises the step of reacting an element or compound having an isotopic mixture containing the desired element with an increased binding energy hydrogen species that bonds to the undesired isotope. Since the bond energy of the reaction product is dependent on the isotope of the undesired element, 25 an increased binding energy species can be selected such that the predominant reaction product contains at least one increased binding energy hydrogen species bound to the undesired isotope, and the desired isotope remains substantially unbound. The compound comprising at least one increased binding energy hydrogen species and the undesired 30 isotope can be separated from the reaction mixture to obtain the desired isotope. The use of the term "isotope" in this context includes an individual element as well as compounds containing the desired 35 isotope.

elemental isotope.

A further method of separating a desired isotope from a mixture of isotopes comprises:

reacting an increased binding energy hydrogen species with an isotopic mixture comprising a molar excess of a desired isotope with respect to the increased binding energy hydrogen species to form a compound enriched in the desired isotope;

separating said compound enriched in the desired isotope from the reaction mixture; and

separating the increased binding energy hydrogen species from the desired isotope to obtain the desired isotope.

Another method of separating a desired isotope from a mixture of isotopes comprises:

reacting a mixture of isotopes with an amount of an increased binding energy hydrogen species sufficient to remove an undesired isotope from a isotopic mixture to form a compound enriched in the undesired isotope, and

removing said compound enriched in the undesired isotope.

The mixture of isotopes can comprise elements and/or compounds containing the isotopes.

Other objects, features, and characteristics of the present invention, as well as the methods of operation and the functions of the related elements, will become apparent upon consideration of the following description and the appended claims with reference to the accompanying drawings, all of which form a part of this specification, wherein like reference numerals designate corresponding parts in the various figures.

### III. BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a schematic drawing of an electrolytic cell hydride reactor in accordance with the present invention;

FIGURE 2 is a schematic drawing of an experimental quartz gas cell hydride reactor in accordance with the present invention;

FIGURE 3 is a schematic drawing of an experimental concentric quartz tubes gas cell hydride reactor in accordance with the present invention;

FIGURE 4 is a schematic drawing of an experimental stainless steel gas cell hydride reactor in accordance with the present invention;

Figure 96A is the positive ToF-SIMS spectrum ( $m/e = 0 - 50$ ) of 99.999%

$KHCO_3$  (HC = hydrocarbon);

Figure 96B is the positive ToF-SIMS spectrum ( $m/e = 50 - 100$ ) of 99.999%  $KHCO_3$  (HC = hydrocarbon);

5 Figure 96C is the positive ToF-SIMS spectrum ( $m/e = 100 - 150$ ) of 99.999%  $KHCO_3$  (HC = hydrocarbon);

Figure 96D is the positive ToF-SIMS spectrum ( $m/e = 150 - 200$ ) of 99.999%  $KHCO_3$  (HC = hydrocarbon);

Figure 97A is the positive ToF-SIMS spectrum ( $m/e = 200 - 300$ ) of 99.999%  $KHCO_3$  (HC = hydrocarbon);

10 Figure 97B is the positive ToF-SIMS spectrum ( $m/e = 300 - 400$ ) of 99.999%  $KHCO_3$  (HC = hydrocarbon);

Figure 97C is the positive ToF-SIMS spectrum ( $m/e = 400 - 500$ ) of 99.999%  $KHCO_3$  (HC = hydrocarbon);

15 Figure 97D is the positive ToF-SIMS spectrum ( $m/e = 500 - 1000$ ) of 99.999%  $KHCO_3$  (HC = hydrocarbon);

Figure 98A is the positive ToF-SIMS spectrum ( $m/e = 0 - 50$ ) of an electrolytic cell sample where HC = hydrocarbon;

Figure 98B is the positive ToF-SIMS spectrum ( $m/e = 50 - 100$ ) of an electrolytic cell sample where HC = hydrocarbon;

20 Figure 98C is the positive ToF-SIMS spectrum ( $m/e = 100 - 150$ ) of an electrolytic cell sample where HC = hydrocarbon;

Figure 98D is the positive ToF-SIMS spectrum ( $m/e = 150 - 200$ ) of an electrolytic cell sample where HC = hydrocarbon;

25 Figure 99A is the positive ToF-SIMS spectrum ( $m/e = 200 - 300$ ) of an electrolytic cell sample where HC = hydrocarbon;

Figure 99B is the positive ToF-SIMS spectrum ( $m/e = 300 - 400$ ) of an electrolytic cell sample where HC = hydrocarbon;

Figure 99C is the positive ToF-SIMS spectrum ( $m/e = 400 - 500$ ) of an electrolytic cell sample where HC = hydrocarbon;

30 Figure 99D is the positive ToF-SIMS spectrum ( $m/e = 500 - 1000$ ) of an electrolytic cell sample where HC = hydrocarbon;

Figure 100 is the 0 to 80 eV binding energy region of a high resolution XPS spectrum of an electrolytic cell sample;

35 Figure 101 is the XPS survey spectrum an electrolytic cell sample with the primary elements identified;

Figure 102 is the magic angle spinning proton NMR spectrum of an electrolytic cell sample;

- Figure 103 is the overlap FTIR spectrum an electrolytic cell sample and the FTIR spectrum of the reference potassium carbonate;
- Figure 104 is the stainless steel gas cell comprising a Ti screen dissociator, potassium metal catalyst, and *KI* as the reactant;
- 5 Figure 105A is the positive ToF-SIMS spectrum ( $m/e = 0 - 50$ ) of the blue crystals;
- Figure 105B is the positive ToF-SIMS spectrum ( $m/e = 50 - 100$ ) of the blue crystals;
- 10 Figure 105C is the positive ToF-SIMS spectrum ( $m/e = 100 - 150$ ) of the blue crystals;
- Figure 105D is the positive ToF-SIMS spectrum ( $m/e = 150 - 200$ ) of the blue crystals;
- 15 Figure 106A is the negative ToF-SIMS spectrum ( $m/e = 0 - 50$ ) of the blue crystals;
- Figure 106B is the negative ToF-SIMS spectrum ( $m/e = 50 - 100$ ) of the blue crystals;
- Figure 106C is the negative ToF-SIMS spectrum ( $m/e = 100 - 150$ ) of the blue crystals;
- 20 Figure 106D is the negative ToF-SIMS spectrum ( $m/e = 150 - 200$ ) of the blue crystals;
- Figure 107 is the XPS survey scan of the blue crystals;
- Figure 108 is the 0-100 eV binding energy region of a high resolution XPS spectrum of the blue crystals;
- 25 Figure 109 is the 0-100 eV binding energy region of a high resolution XPS spectrum of the control *KI*;
- Figure 110 is the  $^1H$  MAS NMR spectrum of the control *KH* relative to external tetramethylsilane (TMS);
- Figure 111 is the  $^1H$  MAS NMR spectra of the blue crystals relative to external tetramethylsilane (TMS);
- 30 Figure 112 is the  $^1H$  NMR spectrum of the blue crystals exposed to air for 1 minute;
- Figure 113 is the  $^1H$  NMR spectrum of the blue crystals exposed to air for 20 minutes;
- Figure 114 is the  $^1H$  NMR spectrum of the blue crystals exposed to air for 40 minutes;
- 35 Figure 115 is the  $^1H$  NMR spectrum of the blue crystals exposed to air for 60 minutes;

- Figure 116 is the FTIR spectra ( $500 - 4000 \text{ cm}^{-1}$ ) of the blue crystals;  
Figure 117 is the FTIR spectra ( $500 - 1500 \text{ cm}^{-1}$ ) of the blue crystals;  
Figure 118 is the results of the Selected Ion Monitoring LC/MS analysis  
of the blue crystals wherein the mass spectrum comprised the  $m/z = 204.6$   
ion signal;
- 5 Figure 119 is the results of the Selected Ion Monitoring LC/MS analysis  
of the blue crystals wherein the mass spectrum comprised the  $m/z = 307.6$   
ion signal;
- 10 Figure 120 is the gas chromatograph of the dihydrino or hydrogen  
released from the blue crystals when the sample was heated to above 600  
 $^{\circ}\text{C}$  with melting;
- 15 Figure 121 is the intensity as a function of time for masses  $m/e = 1$ ,  
 $m/e = 2$ , and  $m/e = 3$  obtained while changing the ionization potential (IP)  
of the mass spectrometer from 30 eV to 70 eV for gas released from  
thermal decomposition of the blue crystals, and
- Figure 122 is the intensity as a function of time for masses  $m/e = 1$ ,  
 $m/e = 2$ , and  $m/e = 3$  obtained while changing the ionization potential (IP)  
of the mass spectrometer from 30 eV to 70 eV for ultrapure hydrogen.

20

#### IV. DETAILED DESCRIPTION OF THE INVENTION

- Formation of a hydrino hydride ion allows for formation of alkali  
and alkaline earth hydrides having enhanced stability or reduced  
reactivity in water. Increased binding energy hydrogen species are  
capable of forming very strong bonds with certain cations and have  
unique properties with many applications such as cutting materials (as a  
replacement for diamond, for example); structural materials and synthetic  
fibers such as novel inorganic polymers. Due to the small mass of the  
hydrino hydride ion, these materials can be made significantly lighter in  
weight than present materials containing conventional anions.
- 25
- 30 Increased binding energy hydrogen species have many additional  
applications such as cathodes for thermionic generators; formation of  
photoluminescent compounds (for example Zintl phase silicides and  
silanes containing increased binding energy hydrogen species); corrosion  
resistant coatings; heat resistant coatings; phosphors for lighting; optical  
35 coatings; optical filters (for example, due to the unique continuum  
emission and absorption bands of the increased binding energy hydrogen

species); extreme ultraviolet laser media (for example, as a compound with a highly positively charged cation); fiber optic cables (for example, as a material with a low attenuation for electromagnetic radiation and a high refractive index); magnets and magnetic computer storage media (for example, as a compound with a ferromagnetic cation such as iron, nickel, or chromium); chemical synthetic processing methods; and refining methods. The specific  $p$  hydrino hydride ion ( $H^{-}(n=1/p)$  where  $p$  is an integer) may be selected to provide the desired property such as voltage following doping with the hydrino hydride ion.

Increased binding energy hydrogen species are useful in mining and refining methods to extract and/or purify a desired element. Increased binding energy hydrogen species may be formulated which are capable of selectively reacting with an element, such as silver, platinum, or gold, of a mixture of elements and/or compounds to form an increased binding energy hydrogen compound containing the desired element. In the case of silver, an exemplary increased binding energy hydrogen compound is  $AgHX$  where  $X$  is a halogen and  $H$  is an increased binding energy hydrogen species. The mixture may be placed in the reaction vessel of the hydrino hydride reactor under conditions such that the reaction of an increased binding energy hydrogen species with the desired element occurs within the reactor. The product may be readily separated from the mixture based on properties of the increased binding energy hydrogen compound using conventional separation methods, such as volatility or solubility. The specific  $p$  hydrino hydride ion ( $H^{-}(n=1/p)$  where  $p$  is an integer) may be selected to provide a desired property of the compound which allows for the extraction or separation of the desired element from the mixture. The compound can be purified from the mixture by the methods disclosed in the Purification of Increased Binding Energy Hydrogen Compounds section of my previous PCT Patent Application, PCT US98/14029 filed on July 7, 1998, which is incorporated herein by reference. The desired element can be isolated by decomposition of the increased binding energy hydrogen compound by methods such as thermal or chemical decomposition.

The reactions resulting in the formation of the increased binding energy hydrogen compounds are useful in chemical etching processes, such as semiconductor etching to form computer chips, for example. Hydrino hydride ions are useful as dopants for semiconductors, to alter

the energies of the conduction and valance bands of the semiconductor materials. Hydrino hydride ions may be incorporated into semiconductor materials by ion implantation, beam epitaxy, or vacuum deposition. The specific  $p$  hydrino hydride ion ( $H^-(n=1/p)$  where  $p$  is an integer) may be selected to provide a desired property such as band gap following doping.

- 5 Due to the high energy released in the formation of a hydrino hydride ion from a hydrino, the hydrino may be a useful etching agent. Hydrinos may be generated such that they collide with the surface to be etched under conditions such that the surface species are oxidized.
- 10 Increased binding energy hydrogen compounds may provide hydrinos. The hydrinos may be supplied to the surface by thermally or chemically decomposing increased binding energy hydrogen compounds. Alternatively, the source of hydrinos may be an electrolytic cell, gas cell, gas discharge cell, or plasma torch cell hydrino hydride reactor of the present invention. To contact hydrinos with the surface to be etched, the object having the surface may be placed in the hydrino hydride reactor, for example. Alternatively, hydrinos may be applied as an atomic beam by methods known to those skilled in the art.

- 20 Hydrino hydride compounds can be formulated for use as semiconductor masking agents. Hydrino species-terminated (versus normal hydrogen-terminated) silicon may be utilized. In one embodiment hydrino species-terminated (versus hydrogen-terminated) silicon is synthesized by exposure of silicon or a silicon compound such as silicon dioxide to hydrinos. Increased binding energy hydrogen compounds may provide hydrinos. The hydrinos may be supplied to the surface by thermally or chemically decomposing increased binding energy hydrogen compounds. Alternatively, the source of hydrinos may be an electrolytic cell, gas cell, gas discharge cell, or plasma torch cell hydrino hydride reactor of the present invention. To contact hydrinos with the silicon reactant, the silicon may be placed in the hydrino hydride reactor, for example. Alternatively, hydrinos may be applied as an atomic beam by methods known to those skilled in the art.
- 25
- 30

- 35 Increased binding energy hydrogen silanes that are stable in air and/or are stable at elevated temperatures are useful sources of pure silicon which may be obtained by decomposition of purified increased binding energy hydrogen silanes. For example, the decomposition to pure silicon may be chemical or thermal.

Due to the extraordinary binding energy of increased binding energy hydrogen species such as hydrino hydride ions, increased binding energy hydrogen compounds may contain protons. Thus, increased binding energy hydrogen compounds may be a source of protons. One 5 method to release protons is thermal decomposition of the increased binding energy hydrogen compounds, preferably in vacuum.

The highly stable hydrino hydride ion has application as the negative ion of the electrolyte of a high voltage electrolytic cell. In a further application, a hydrino hydride ion with extreme stability 10 represents a significant improvement as the product of a cathode half reaction of a fuel cell or battery over conventional cathode products of present batteries and fuel cells. The hydrino hydride reaction of Eq. (11) releases significantly more energy than oxidants used in conventional batteries.

15 A further advanced battery application of hydrino hydride ions is in the fabrication of batteries. A battery comprising, as an oxidant compound, a hydrino hydride compound formed of a highly oxidized cation and a hydrino hydride ion ("hydrino hydride battery"), has a lighter weight, higher voltage, higher power, and greater energy density 20 than a conventional battery having a cell voltage of about one volt. In one embodiment, a hydrino hydride battery has a cell voltage of about 100 times that of conventional batteries. The hydrino hydride battery also has a lower resistance than conventional batteries. Thus, the power 25 of the novel battery can be more than 10,000 times the power of conventional batteries. Furthermore, a hydrino hydride battery can be formulated which posses energy densities of greater than 100,000 watt hours per kilogram. In contrast, the most advanced of conventional batteries have energy densities of less than 200 watt hours per kilogram.

30 The present battery may further comprise an electronic activation circuit which is activated by a user specific input signal called a "password" or "key" such as a swipe card signal. Or the battery may be activated by a signal transmitted to the battery from an electricity supplier such as an electric utility company which permits the battery to be charged. In the latter case, the battery may further comprise an 35 electronic device such as a computer chip which may be installed by the electricity supplier. The signal which activates the battery to be charged may be transmitted to the battery through electrical leads of the charger

for example. The activation may signal a debit to the electricity consumer based on the electricity consumed during battery charging.

The catalysis of hydrogen by catalysts such as potassium ions (Eqs. 3-5)) and rubidium (Eqs. 6-8)) to form hydrino atoms and hydrino hydride ions may result in the emission of extreme ultraviolet (EUV) photons such as 912 Å and 304 Å. Extreme UV photons may ionize or excite molecular hydrogen resulting in molecular hydrogen emission which includes well characterized ultraviolet lines such as the Balmer series. The hydrogen emission or the hydrogen emission further converted to other wavelengths using a phosphor, for example, is a lighting source of the present invention. The light source may produce wavelengths such as extreme ultraviolet, ultraviolet, visible, and infrared wavelengths.

Due to the rapid kinetics and the extraordinary exothermic nature of the reactions of increased binding energy hydrogen compounds, particularly hydrino hydride compounds, other applications include munitions, explosives, propellants, and solid fuels.

The selectivity of hydrino atoms and hydride ions in forming bonds with specific isotopes based on a differential in bond energy provides a means to purify desired isotopes of elements.

Hydrogen polymers and inorganic hydrogen polymers comprising increased binding energy hydrogen species may be useful as superconductors having a high transition temperature.

### 1. HYDRIDE ION

A hydrino atom  $H\left[\frac{a_H}{p}\right]$  reacts with an electron to form a corresponding hydrino hydride ion  $H^-(n=1/p)$  as given by Eq. (11). Hydride ions are a special case of two-electron atoms each comprising a nucleus and an "electron 1" and an "electron 2". The derivation of the binding energies of two-electron atoms is given by the '99 Mills GUT. A brief summary of the hydride binding energy derivation follows whereby the equation numbers of the format (#.###) correspond to those given in the '99 Mills GUT.

The hydride ion comprises two indistinguishable electrons bound to a proton of  $Z=+1$ . Each electron experiences a centrifugal force, and the balancing centripetal force (on each electron) is produced by the electric

force between the electron and the nucleus. In addition, a magnetic force exists between the two electrons causing the electrons to pair.

### 1.1 Determination of the Orbitssphere Radius, $r_n$

- 5 Consider the binding of a second electron to a hydrogen atom to form a hydride ion. The second electron experiences no central electric force because the electric field is zero outside of the radius of the first electron. However, the second electron experiences a magnetic force due to electron 1 causing it to spin pair with electron 1. Thus, electron 1  
 10 experiences the reaction force of electron 2 which acts as a centrifugal force. The force balance equation can be determined by equating the total forces acting on the two bound electrons taken together. The force balance equation for the paired electron orbitssphere is obtained by equating the forces on the mass and charge densities. The centrifugal  
 15 force of both electrons is given by Eq. (7.1) and Eq. (7.2) where the mass is  $2m_e$ . Electric field lines end on charge. Since both electrons are paired at the same radius, the number of field lines ending on the charge density of electron 1 equals the number that end on the charge density of electron 2. The electric force is proportional to the number of field lines;  
 20 thus, the centripetal electric force,  $F_{ele}$ , between the electrons and the nucleus is represented by

$$F_{ele(electron\ 1,2)} = \frac{\frac{1}{2}e^2}{4\pi\epsilon_0 r_n^2} \quad (42)$$

- 25 where  $\epsilon_0$  is the permittivity of free-space. The outward magnetic force on the two paired electrons is given by the negative of Eq. (7.15) where the mass is  $2m_e$ . The outward centrifugal force and magnetic forces on electrons 1 and 2 are balanced by the electric force ,

$$\frac{\hbar^2}{2m_e r_2^3} = \frac{\frac{1}{2}e^2}{4\pi\epsilon_0 r_2^2} - \frac{1}{Z} \frac{\hbar^2}{2m_e r_2^3} \sqrt{s(s+1)} \quad (43)$$

where  $Z=1$ . Solving for  $r_2$ ,

$$r_2 = r_1 = a_0 \left( 1 + \sqrt{s(s+1)} \right); s = \frac{1}{2} \quad (44)$$

- 30 That is, the final radius of electron 2,  $r_2$ , is given by Eq. (44); this is also the final radius of electron 1.

### 1.2 Binding Energy

During ionization, electron 2 moves to infinity. By the selection rules for absorption of electromagnetic radiation dictated by conservation of angular momentum, absorption of a photon causes the spin axes of the 5 antiparallel spin-paired electrons to become parallel. The unpairing energy,  $E_{unpairing(magnetic)}$ , is given by Eq. (7.30) and Eq. (44) multiplied by two because the magnetic energy is proportional to the square of the magnetic field as derived in Eqs. (1.122-1.129). A repulsive magnetic force exists on the electron to be ionized due to the parallel alignment of 10 the spin axes. The energy to move electron 2 to a radius which is infinitesimally greater than that of electron 1 is zero. In this case, the only force acting on electron 2 is the magnetic force. Due to conservation of energy, the potential energy change to move electron 2 to infinity to ionize the hydride ion can be calculated from the magnetic force of Eq. 15 (43). The magnetic work,  $E_{magwork}$ , is the negative integral of the magnetic force (the second term on the right side of Eq. (43)) from  $r_2$  to infinity,

$$E_{magwork} = \int_{r_2}^{\infty} \frac{\hbar^2}{2m_e r^3} \sqrt{s(s+1)} dr \quad (45)$$

where  $r_2$  is given by Eq. (44). The result of the integration is

$$E_{magwork} = -\frac{\hbar^2 \sqrt{s(s+1)}}{4m_e a_0^2 [1 + \sqrt{s(s+1)}]^2} \quad (46)$$

20 where  $s = \frac{1}{2}$ . By moving electron 2 to infinity, electron 1 moves to the radius  $r_1 = a_H$ , and the corresponding magnetic energy,  $E_{electron 1 final(magnetic)}$ , is given by Eq. (7.30). In the present case of an inverse squared central field, the binding energy is one half the negative of the potential energy [Fowles, G. R., Analytical Mechanics, Third Edition, Holt, Rinehart, and Winston, New York, (1977), pp. 154-156]. Thus, the binding energy can 25 be determined by subtracting the two magnetic energy terms from one half the negative of the magnetic work wherein  $m_e$  is the electron reduced mass  $\mu_e$  given by Eq. (1.167) due to the electrodynamic magnetic force between electron 2 and the nucleus given by one half that of Eq. (1.164). 30 The factor of one half follows from Eq. (43).

$$\begin{aligned}
 \text{Binding Energy} &= -\frac{1}{2} E_{\text{magwork}} - E_{\text{electron } 1 \text{ final}}(\text{magnetic}) - E_{\text{unpairing}}(\text{magnetic}) \\
 &= \frac{\hbar^2 \sqrt{s(s+1)}}{8\mu_e a_0^2 [1 + \sqrt{s(s+1)}]^2} - \frac{\pi\mu_0 e^2 \hbar^2}{m_e^2 a_0^3} \left( 1 + \frac{2^2}{[1 + \sqrt{s(s+1)}]^3} \right) \quad (47)
 \end{aligned}$$

- The binding energy of the ordinary hydride ion  $H^- (n=1)$  is  $0.75402 \text{ eV}$  according to Eq. (47). The experimental value given by Dean [John A. Dean, Editor, Lange's Handbook of Chemistry, Thirteenth Edition, McGraw-Hill Book Company, New York, (1985), p. 3-10.] is  $0.754209 \text{ eV}$  which corresponds to a wavelength of  $\lambda = 1644 \text{ nm}$ . Thus, both values approximate to a binding energy of about  $0.8 \text{ eV}$  for normal hydride ion.
- 5

### 1.3 Hydrino Hydride Ion

The hydrino atom  $H(1/2)$  can form a stable hydride ion, namely, the hydrino hydride ion  $H^-(n=1/2)$ . The central field of the hydrino atom is twice that of the hydrogen atom, and it follows from Eq. (43) that the radius of the hydrino hydride ion  $H^-(n=1/2)$  is one half that of an ordinary hydrogen hydride ion,  $H^-(n=1)$ , given by Eq. (44).

$$r_2 = r_1 = \frac{a_0}{2} \left(1 + \sqrt{s(s+1)}\right); s = \frac{1}{2} \quad (48)$$

The energy follows from Eq. (47) and Eq. (48).

$$\text{Binding Energy} = -\frac{1}{2} E_{\text{magwork}} - E_{\text{electron 1 final (magnetic)}} - E_{\text{unpairing (magnetic)}}$$

$$= \frac{\hbar^2 \sqrt{s(s+1)}}{8\mu_e a_0^2 \left[ \frac{1 + \sqrt{s(s+1)}}{2} \right]^2} - \frac{\pi\mu_0 e^2 \hbar^2}{m_e^2 a_0^3} \left( 1 + \frac{2^2}{\left[ \frac{1 + \sqrt{s(s+1)}}{2} \right]^3} \right) \quad (49)$$

10 The binding energy of the hydrino hydride ion  $H^-(n=1/2)$  is 3.047 eV according to Eq. (49), which corresponds to a wavelength of  $\lambda = 407 \text{ nm}$ . In general, the central field of hydrino atom  $H(n=1/p)$ ;  $p = \text{integer}$  is  $p$  times that of the hydrogen atom. Thus, the force balance equation is

$$\frac{\hbar^2}{2m_e r_2^3} = \frac{\frac{p}{2} e^2}{4\pi\epsilon_0 r_2^2} - \frac{1}{Z} \frac{\hbar^2}{2m_e r_2^3} \sqrt{s(s+1)} \quad (50)$$

15 where  $Z=1$  because the field is zero for  $r > r_1$ . Solving for  $r_2$ ,

$$r_2 = r_1 = \frac{a_0}{p} \left(1 + \sqrt{s(s+1)}\right); s = \frac{1}{2} \quad (51)$$

From Eq. (51), the radius of the hydrino hydride ion  $H^-(n=1/p)$ ;  $p = \text{integer}$  is  $\frac{1}{p}$  that of atomic hydrogen hydride,  $H^-(n=1)$ , given by Eq. (44). The energy follows from Eq. (50) and Eq. (51).

$$\text{Binding Energy} = -\frac{1}{2} E_{\text{magwork}} - E_{\text{electron 1 final (magnetic)}} - E_{\text{unpairing (magnetic)}}$$

$$= \frac{\hbar^2 \sqrt{s(s+1)}}{8\mu_e a_0^2 \left[ \frac{1 + \sqrt{s(s+1)}}{p} \right]^2} - \frac{\pi\mu_0 e^2 \hbar^2}{m_e^2 a_0^3} \left( 1 + \frac{2^2}{\left[ \frac{1 + \sqrt{s(s+1)}}{p} \right]^3} \right) \quad (52)$$

TABLE 1, *supra*, provides the binding energy of the hydrino hydride ion  $H^-(n=1/p)$  as a function of  $p$  according to Eq. (52).

## 2. INORGANIC HYDROGEN AND HYDROGEN POLYMER COMPOUNDS

In a further embodiment of the present invention, hydrino hydride ions can be reacted or bonded to any atom of the periodic chart 5 or positively or negatively charged ion thereof such as an alkali or alkaline earth cation, or a proton. Hydrino hydride ions may also react with or bond to any compound, organic molecule, inorganic molecule, organometallic molecule or compound, metal, nonmetal, or semiconductor to form an organic molecule, inorganic molecule, 10 compound, metal, nonmetal, organometallic, or semiconductor.

Additionally, hydrino hydride ions may react with or bond to ordinary  $H_2^+$ , ordinary  $H_3^+$ ,  $H_3^+(1/p)$ ,  $H_4^+(1/p)$ , or dihydrino molecular ions

$H_2^+ \left[ 2c' = \frac{2a_o}{p} \right]^+$ . Dihydrino molecular ions may bond to hydrino hydride ions such that the binding energy of the reduced dihydrino molecular 15 ion, the dihydrino molecule  $H_2^+ \left[ 2c' = \frac{\sqrt{2}a_o}{p} \right]$ , is less than the binding energy of the hydrino hydride ion  $H^- \left( \frac{1}{p} \right)$  of the compound.

The reactants which may react with hydrino hydride ions include neutral atoms or molecules, negatively or positively charged atomic and molecular ions, and free radicals. In one embodiment to form hydrino 20 hydride containing compounds, hydrino hydride ions are reacted with a metal. Thus, in one embodiment of the electrolytic cell hydride reactor, hydrino, hydrino hydride ion, or dihydrino produced during operation at the cathode reacts with the cathode material to form a compound. In one embodiment of the gas cell hydride reactor, hydrino, hydrino 25 hydride ion, or dihydrino produced during operation reacts with the dissociation material or source of atomic hydrogen to form a compound. A metal-hydribo hydride material can thus be produced.

Exemplary types of compounds of the present invention include those that follow. Each compound of the invention includes at least one increased binding energy hydrogen species. The compounds of the 30 present invention may further comprise ordinary hydrogen species, in addition to one or more of the increased binding energy hydrogen species.

$H^-(1/p)H_3^+$ ;  $MH$ ,  $MH_2$ , and  $M_2H_2$  where  $M$  is an alkali cation (in the case of  $M_2H_2$ , the alkali cations may be different) and  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H$ ;  $MH_n$ ,  $n=1$  to  $2$  where  $M$  is an alkaline earth cation and  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H$ ;  $MHX$  where  $M$  is an alkali cation,  $X$  is a neutral atom or molecule or a singly negative charged anion, and  $H$  is an increased binding energy hydrogen species;  $MHX$  where  $M$  is an alkaline earth cation,  $X$  is a singly negative charged anion, and  $H$  is an increased binding energy hydrogen species;  $MHX$  where  $M$  is an alkaline earth cation,  $X$  is a doubly negative charged anion, and  $H$  is an increased binding energy hydrogen species;  $M_2HX$  where  $M$  is an alkali cation (the alkali cations may be different),  $X$  is a singly negative charged anion, and  $H$  an increased binding energy hydrogen species;  $MH_n$ ,  $n=1$  to  $5$  where  $M$  is an alkaline cation and  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H$ ;  $M_2H_n$ ,  $n=1$  to  $4$  where  $M$  is an alkaline earth cation and  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H$  (the alkaline earth cations may be different);  $M_2XH_n$ ,  $n=1$  to  $3$  where  $M$  is an alkaline earth cation,  $X$  is a singly negative charged anion, and  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H$  (the alkaline earth cations may be different);  $M_2X_2H_n$ ,  $n=1$  to  $2$  where  $M$  is an alkaline earth cation,  $X$  is a singly negative charged anion, and  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H$  (the alkaline earth cations may be different);  $M_2X_3H$  where  $M$  is an alkaline earth cation,  $X$  is a singly negative charged anion, and  $H$  is an increased binding energy hydrogen species (the alkaline earth cations may be different);  $M_2XH_n$ ,  $n=1$  to  $2$  where  $M$  is an alkaline earth cation,  $X$  is a doubly negative charged anion, and  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of

multiple  $H$  (the alkaline earth cations may be different):  $M_2XX'H$  where  $M$  is an alkaline earth cation,  $X$  is a singly negative charged anion,  $X'$  is a doubly negative charged anion, and  $H$  is an increased binding energy hydrogen species (the alkaline earth cations may be different);  
5  $MM'H_n$   $n=1$  to  $3$  where  $M$  is an alkaline earth cation,  $M'$  is an alkali metal cation, and  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H$ ;  $MM'XH_n$   $n=1$  to  $2$  where  $M$  is an alkaline earth cation,  $M'$  is an alkali metal cation,  $X$  is a singly negative charged anion,  
10 and  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H$ ;  $MM'XH$  where  $M$  is an alkaline earth cation,  $M'$  is an alkali metal cation,  $X$  is a doubly negative charged anion, and  $H$  is an increased binding energy hydrogen species;  $MM'XX'H$  where  $M$  is an  
15 alkaline earth cation,  $M'$  is an alkali metal cation,  $X$  and  $X'$  are each a singly negative charged anion, and  $H$  is an increased binding energy hydrogen species;  $H_nS$   $n=1$  to  $2$  where  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H$ ;  $MAIH_n$   $n=1$  to  $6$   
20 where  $M$  is an alkali or alkaline earth cation and  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H$ ;  $MH_n$   $n=1$  to  $6$  where  $M$  is a transition, inner transition, or rare earth element cation such as nickel and  $H$  is at least one increased binding  
25 energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H$ ;  $MNiH_n$   $n=1$  to  $6$  where  $M$  is an alkali cation, alkaline earth cation, silicon, or aluminum and  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the  
30 case of multiple  $H$ , and nickel may be substituted by another transition metal, inner transition, or rare earth cation;  $TiH_n$   $n=1$  to  $4$  where  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H$ ;  $Al,H_n$   $n=1$  to  $4$  where  $H$  is at least one increased binding energy  
35 hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H$ ;  $AlH_n$   $n=1$  to  $4$  where  $H$  is at

least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H; MXAIX H_n$ ,  $n=1$  to  $2$  where  $M$  is an alkali or alkaline earth cation,  $X$  and  $X'$  are each a singly negative charged anion, or a double negative

5 charged anion,  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H$ , and another cation such as  $Si$  may replace  $Al$ ;  $[KH_m KCO_3]_n$   $m,n=integer$  where  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least

10 one ordinary hydrogen species in the case of multiple  $H$ ;  $[KHKOH]_n$   $n=integer$  where  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species;  $[KHKNO_3]_n$   $n=integer$  wherein  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H$ ;  $[KH_m KNO_3]_n$   $nX^-$   $m,n=integer$  where  $X$  is a singly negative charged anion, and  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H$ ;  $[MH_m M' X]_n$   $m,n=integer$  comprising a neutral

15 compound or an anion or cation where  $M$  and  $M'$  are each an alkali or alkaline earth cation,  $X$  is a singly negative charged anion or a doubly negative charged anion, and  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H$ ;  $[MH_m M' X]_n^+ nX^-$   $m,n=integer$

20 wherein  $M$  and  $M'$  are each an alkali or alkaline earth cation,  $X$  and  $X'$  are each a singly negative charged anion or a doubly negative charged anion, and  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H$ ;  $[MH_m M' X]_n^{m'+} n'X^-$   $m,m',n,n'=integer$  where  $M$  and

25  $M'$  are each an alkali or alkaline earth cation,  $X$  and  $X'$  are each a singly negative charged anion or a doubly negative charged anion, and  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H$ ;  $[MH_m M' X]_n^- nM''^+$   $m,n=integer$  where  $M$ ,  $M'$ , and  $M''$  are each an

30 alkali or alkaline earth cation,  $X$  and  $X'$  are each a singly negative

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charged anion or a doubly negative charged anion, and  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H$ ;  $[MH_mM'X]^{m'-} n'M^{++}$   $m,m',n,n' = \text{integer where } M, M', \text{ and } M' \text{ are each}$

5  $\text{an alkali or alkaline earth cation, } X \text{ and } X' \text{ are each a singly negative charged anion or a doubly negative charged anion, and } H \text{ is at least one increased binding energy hydrogen species in the case of multiple } H,$  and may optionally comprise at least one ordinary hydrogen species;  $[MH_m]^{m'+} n'X^- m,m',n,n' = \text{integer where } M \text{ is alkali or alkaline earth,}$

10 organic, organometallic, inorganic, or ammonium cation,  $X$  is a singly or doubly negative charged anion, and  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H;$   $[MH_m]^{m'-} n'M^+ m,m',n,n' = \text{integer where } M \text{ and } M' \text{ are each an alkali or}$

15 alkaline earth, organic, organometallic, inorganic, or ammonium cation and  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H;$   $M(H_{10})_n n = \text{integer where } M \text{ is other element such as any atom, molecule, or compound, and } H \text{ is at least one increased}$

20 binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species;  $M(H_{10})_n n = \text{integer where } M \text{ is an increased binding energy hydrogen compound, and } H \text{ is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species; } M^+(H_{16})^- n = \text{integer}$

25 where  $M$  is other element such as an alkali, organic, organometallic, inorganic, or ammonium cation, and  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species;  $M^+(H_{16})^- n = \text{integer where } M \text{ is an increased binding energy hydrogen compound, and } H \text{ is at least one increased}$

30 binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species;  $M(H_{16})_n n = \text{integer where } M \text{ is other element such as any atom, molecule, or compound, and } H \text{ is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species; } M(H_{16})_n n = \text{integer where }$

35  $M \text{ is an increased binding energy hydrogen compound, and } H \text{ is at least}$

one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species;  $M(H_{24})_n$   $n = \text{integer}$  where M is other element such as any atom, molecule, or compound, and H is at least one increased binding energy hydrogen species, and may 5 optionally comprise at least one ordinary hydrogen species;  $M(H_{24})_n$   $n = \text{integer}$  where M is an increased binding energy hydrogen compound, and H is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species;  $M(H_{60})_n$   $n = \text{integer}$  where M is other element such as any atom, molecule, or 10 compound, and H is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species;  $M(H_{60})_n$   $n = \text{integer}$  where M is an increased binding energy hydrogen compound, and H is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species;  $M(H_{70})_n$   $n = \text{integer}$  where M is other element such as 15 any atom, molecule, or compound, and H is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species;  $M(H_{70})_n$   $n = \text{integer}$  where M is an increased binding energy hydrogen compound, and H is at least one 20 increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species;  $M(H_{10})_q(H_{16})_r(H_{24})_s(H_{60})_t(H_{70})_u$   $q,r,s,t,u = \text{integer}$  wherein M is other element such as any atom, molecule, or compound, each integer  $q,r,s,t,u$  may be zero but not all integers may be zero, the compound contains at least one 25 H, the monomers may be arranged in any order, H is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species;  $M(H_{10})_q(H_{16})_r(H_{24})_s(H_{60})_t(H_{70})_u$   $q,r,s,t,u = \text{integer}$  wherein M is an increased binding energy hydrogen compound, each integer  $q,r,s,t,u$  may be zero 30 but not all integers may be zero, the compound contains at least one H, the monomers may be arranged in any order, H is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species; MX where M is positive, neutral, or negative and is selected from the list of  $H_{16}$ ,  $H_{16}H$ ,  $H_{16}H_2$ ,  $H_{24}H_{23}$ ,  $OH_{22}$ ,  $OH_{23}$ ,  $OH_{24}$ ,  $MgH_2H_{16}$ ,  $NaH_3H_{16}$ ,  $H_{24}H_2O$ ,  $CNH_{16}$ ,  $CH_{30}$ ,  $SiH_4H_{16}$ ,  $(H_{16})_3H_{15}$ ,  
35

$SiH_3(H_{16})_2$ ,  $(H_{16})_4$ ,  $H_{70}$ ,  $Si_2H_6H_{16}$ ,  $(SiH_4)_2H_{16}$ ,  $SiH_4(H_{16})_3$ ,  $CH_{70}$ ,  $NH_{69}$ ,  $NH_{70}$ ,  $NHH_{70}$ ,  
 $OH_{70}$ ,  $H_2OH_{70}$ ,  $FH_{70}$ ,  $H_3OH_{70}$ ,  $SiH_2H_{60}$ ,  $Si(H_{16})_3H_{15}$ ,  $Si(H_{16})_4$ ,  $Si_2H_6(H_{16})_2$ ,  $Si_2H_7(H_{16})_2$ ,  
 $SiH_3(H_{16})_4$ ,  $(SiH_4)_2(H_{16})_2$ ,  $O_2(H_{16})_4$ ,  $SiH_4(H_{16})_4$ ,  $NOH_{70}$ ,  $O_2H_{69}$ ,  $HONH_{70}$ ,  $O_2H_{70}$ ,  
 $H_2ONH_{70}$ ,  $H_3O_2H_{70}$ ,  $Si_2H_6(H_{24})_2$ ,  $Si_2H_6(H_{16})_3$ ,  $(SiH_4)_3H_{16}$ ,  $(SiH_4)_2(H_{16})_3$ ,  $(OH_{23})H_{16}H_{70}$ ,  
5  $(OH_{24})H_{16}H_{70}$ ,  $Si_3H_{10}(H_{16})_2$ ,  $Si_2H_{70}$ ,  $Si_3H_{11}(H_{16})_2$ ,  $Si_2H_7(H_{16})_3$ ,  $(SiH_4)_3(H_{16})_2$ ,  
 $(SiH_4)_2(H_{16})_4$ ,  $NaOSiH_2(H_{16})_4$ ,  $NaKH H_{70}$ ,  $Si_2H_7(H_{70})$ ,  $Si_3H_9(H_{16})_3$ ,  $Si_3H_{10}(H_{16})_3$ ,  
 $Si_2H_6(H_{16})_5$ ,  $(SiH_4)_4H_{16}$ ,  $(SiH_4)_3(H_{16})_3$ ,  $Na_2OSiH_2(H_{16})_4$ ,  $Si_3H_8(H_{16})_4$ ,  $Na_2KH H_{70}$ ,  
 $Si_3H_9(H_{16})_4$ ,  $Na_2HKH H_{70}$ ,  $SO(H_{16})_6(H_{15})$ ,  $SH_2(OH_{23})H_{16}H_{70}$ ,  $SO(H_{16})_7$ ,  
 $Mg_2H_2H_{23}H_{16}H_{70}$ ,  $(SiH_4)_4(H_{16})_2$ ,  $(SiH_4)_3(H_{16})_4$ ,  $KH_3O(H_{16})_2H_{70}$ ,  $KH_5O(H_{16})_2H_{70}$ ,  
10  $K(OH_{23})H_{16}H_{70}$ ,  $K_2OH H_{70}$ ,  $NaKHO_2H_{70}$ ,  $NaOHNaO_2 H_{70}$ ,  $HNO_3 O_2 H_{70}$ ,  $Rb(H_{16})_5$ ,  
 $Si_3H_{11}H_{70}$ ,  $KNO_2(H_{16})_5$ ,  $(SiH_4)_4(H_{16})_3$ ,  $KKH(H_{16})_7$ ,  $(SiH_4)_4(H_{16})_4$ ,  $(KH_2)_2(H_{16})_3H_{70}$ ,  
 $(NiH_2)_2HCl(H_{16})_2H_{70}$ ,  $Si_5OH_{102}$ ,  $(SiH_3)_7(H_{16})_5$ ,  $Na_3O_3(SiH_3)_{10}SiH(H_{16})_5$ , X is other  
element, and H is at least one increased binding energy hydrogen  
15 species, and may optionally comprise at least one ordinary hydrogen  
species; MX where M is positive, neutral, or negative and is selected  
from the list of  $H_{16}$ ,  $H_{16}H$ ,  $H_{16}H_2$ ,  $H_{24}H_{23}$ ,  $OH_{22}$ ,  $OH_{23}$ ,  $OH_{24}$ ,  $MgH_2 H_{16}$ ,  $NaH_3 H_{16}$ ,  
 $H_{24}H_2O$ ,  $CNH_{16}$ ,  $CH_{30}$ ,  $SiH_4H_{16}$ ,  $(H_{16})_3H_{15}$ ,  $SiH_4(H_{16})_2$ ,  $(H_{16})_4$ ,  $H_{70}$ ,  $Si_2H_6H_{16}$ ,  
 $(SiH_4)_2H_{16}$ ,  $SiH_4(H_{16})_3$ ,  $CH_{70}$ ,  $NH_{69}$ ,  $NH_{70}$ ,  $NHH_{70}$ ,  $OH_{70}$ ,  $H_2OH_{70}$ ,  $FH_{70}$ ,  $H_3OH_{70}$ ,  
 $SiH_2H_{60}$ ,  $Si(H_{16})_3H_{15}$ ,  $Si(H_{16})_4$ ,  $Si_2H_6(H_{16})_2$ ,  $Si_2H_7(H_{16})_2$ ,  $SiH_3(H_{16})_4$ ,  $(SiH_4)_2(H_{16})_2$ ,  
20  $O_2(H_{16})_4$ ,  $SiH_4(H_{16})_4$ ,  $NOH_{70}$ ,  $O_2H_{69}$ ,  $HONH_{70}$ ,  $O_2H_{70}$ ,  $H_2ONH_{70}$ ,  $H_3O_2H_{70}$ ,  $Si_2H_6(H_{24})_2$ ,  
 $Si_2H_6(H_{16})_3$ ,  $(SiH_4)_3H_{16}$ ,  $(SiH_4)_2(H_{16})_3$ ,  $(OH_{23})H_{16}H_{70}$ ,  $(OH_{24})H_{16}H_{70}$ ,  $Si_3H_{10}(H_{16})_2$ ,  
 $Si_2H_{70}$ ,  $Si_3H_{11}(H_{16})_2$ ,  $Si_2H_7(H_{16})_4$ ,  $(SiH_4)_3(H_{16})_2$ ,  $(SiH_4)_2(H_{16})_4$ ,  $NaOSiH_2(H_{16})_4$ ,  
 $NaKH H_{70}$ ,  $Si_2H_7(H_{70})$ ,  $Si_3H_9(H_{16})_3$ ,  $Si_3H_{10}(H_{16})_3$ ,  $Si_2H_6(H_{16})_5$ ,  $(SiH_4)_4H_{16}$ ,  $(SiH_4)_3(H_{16})_3$ ,  
 $Na_2OSiH_2(H_{16})_4$ ,  $Si_3H_8(H_{16})_4$ ,  $Na_2KH H_{70}$ ,  $Si_3H_9(H_{16})_4$ ,  $Na_2HKH H_{70}$ ,  $SO(H_{16})_6(H_{15})$ ,  
25  $SH_2(OH_{23})H_{16}H_{70}$ ,  $SO(H_{16})_7$ ,  $Mg_2H_2H_{23}H_{16}H_{70}$ ,  $(SiH_4)_4(H_{16})_2$ ,  $(SiH_4)_3(H_{16})_4$ ,  
 $KH_3O(H_{16})_2H_{70}$ ,  $KH_5O(H_{16})_2H_{70}$ ,  $K(OH_{23})H_{16}H_{70}$ ,  $K_2OH H_{70}$ ,  $NaKHO_2H_{70}$ ,  
 $NaOHNaO_2 H_{70}$ ,  $HNO_3 O_2 H_{70}$ ,  $Rb(H_{16})_5$ ,  $Si_3H_{11}H_{70}$ ,  $KNO_2(H_{16})_5$ ,  $(SiH_4)_4(H_{16})_3$ ,  
 $KKH(H_{16})_7$ ,  $(SiH_4)_4(H_{16})_4$ ,  $(KH_2)_2(H_{16})_3H_{70}$ ,  $(NiH_2)_2HCl(H_{16})_2H_{70}$ ,  $Si_5OH_{102}$ ,  
 $(SiH_3)_7(H_{16})_5$ ,  $Na_3O_3(SiH_3)_{10}SiH(H_{16})_5$ , X is an increased binding energy  
30 hydrogen compound, and H is at least one increased binding energy  
hydrogen species, and may optionally comprise at least one ordinary  
hydrogen species;  $M(H_x)_n$  x = integer from 8 to 10; n = integer where M is other  
element such as any atom, molecule, or compound, and H is at least one  
increased binding energy hydrogen species, and may optionally

comprise at least one ordinary hydrogen species;  $M(H_x)_n$   
x = integer from 8 to 10; n = integer where M is an increased binding energy  
hydrogen compound, and H is at least one increased binding energy  
hydrogen species, and may optionally comprise at least one ordinary  
5 hydrogen species;  $M^+(H_x)_n$  x = integer from 14 to 18; n = integer where M is  
other element such as an alkali, organic, organometallic, inorganic, or  
ammonium cation, and H is at least one increased binding energy  
hydrogen species, and may optionally comprise at least one ordinary  
hydrogen species;  $M^+(H_x)_n$  x = integer from 14 to 18; n = integer where M is an  
10 increased binding energy hydrogen compound, and H is at least one  
increased binding energy hydrogen species, and may optionally  
comprise at least one ordinary hydrogen species;  $M(H_x)_n$   
x = integer from 14 to 18; n = integer where M is other element such as any  
atom, molecule, or compound, and H is at least one increased binding  
15 energy hydrogen species, and may optionally comprise at least one  
ordinary hydrogen species;  $M(H_x)_n$  x = integer from 14 to 18; n = integer where  
M is an increased binding energy hydrogen compound, and H is at least  
one increased binding energy hydrogen species, and may optionally  
comprise at least one ordinary hydrogen species;  $M(H_x)_n$   
20 x = integer from 22 to 26; n = integer where M is other element such as any  
atom, molecule, or compound, and H is at least one increased binding  
energy hydrogen species, and may optionally comprise at least one  
ordinary hydrogen species;  $M(H_x)_n$  x = integer from 22 to 26; n = integer where  
M is an increased binding energy hydrogen compound, and H is at least  
25 one increased binding energy hydrogen species, and may optionally  
comprise at least one ordinary hydrogen species;  $M(H_x)_n$   
x = integer from 58 to 62; n = integer where M is other element such as any  
atom, molecule, or compound, and H is at least one increased binding  
energy hydrogen species, and may optionally comprise at least one  
30 ordinary hydrogen species;  $M(H_x)_n$  x = integer from 58 to 62; n = integer where  
M is an increased binding energy hydrogen compound, and H is at least  
one increased binding energy hydrogen species, and may optionally  
comprise at least one ordinary hydrogen species;  $M(H_x)_n$   
x = integer from 68 to 72; n = integer where M is other element such as any  
35 atom, molecule, or compound, and H is at least one increased binding

energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species;  $M(H_x)_n$   $x = \text{integer from 68 to 72}$ ;  $n = \text{integer where } M \text{ is an increased binding energy hydrogen compound, and } H \text{ is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species;}$

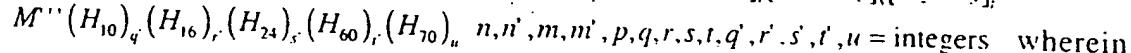
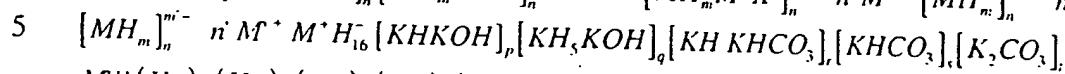
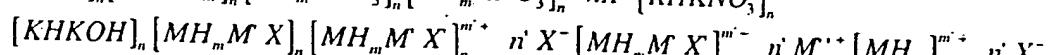
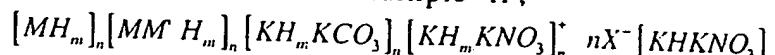
$M(H_x)_q(H_x)_r(H_y)_s(H_y)_t(H_z)_u$   $q,r,s,t,u = \text{integer}; x = \text{integer from 8 to 12}; x' = \text{integer from 14 to 18}; y = \text{integer from 22 to 26}; y' = \text{integer from 58 to 62}; z = \text{integer from 68 to 72 wherein } M \text{ is other element such as any atom, molecule, or compound, each integer } q,r,s,t,u \text{ may be zero but not all integers may be zero, the compound contains at least one } H, \text{ the monomers may be arranged in any order, } H \text{ is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species; } M(H_x)_q(H_x)_r(H_y)_s(H_y)_t(H_z)_u$   $q,r,s,t,u = \text{integer}; x = \text{integer from 8 to 12}; x' = \text{integer from 14 to 18}; y = \text{integer from 22 to 26}; y' = \text{integer from 58 to 62}; z = \text{integer from 68 to 72 wherein } M \text{ is an increased binding energy hydrogen compound, wherein each integer } q,r,s,t,u \text{ may be zero but not all integers may be zero, the compound contains at least one } H, \text{ the monomers may be arranged in any order, } H \text{ is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species; }$

$[KHKOH]_p[KH_5KOH]_q[KH_2KHCO_3]_r[KHCO_3]_s[K_2CO_3]$   $p,q,r,s,t = \text{integer}$  wherein each integer  $p,q,r,s,t$  may be zero but not all integers may be zero, the compound contains at least one  $H$ , the monomers may be arranged in any order,  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species;

$[MH_m]_n[MM' H_m]_n[KH_m KCO_3]_n[KH_m KNO_3]^{n'} nX^- [KHKNO_3]_n[KHKOH]_n[MH_m M' X]_n$   
 $[MH_m M' X]^{n''} n' X^- [MH_m M' X]^{n''' -} n'' M''^+ [MH_m]^{n'''}_n n' X^- [MH_m]^{n'''' -} n''' M''^+ M'' H_{16}^-$   
 $[KHKOH]_p[KH_5KOH]_q[KH_2KHCO_3]_r[KHCO_3]_s[K_2CO_3]$   $n,n',m,m',p,q,r,s,t = \text{integers}$

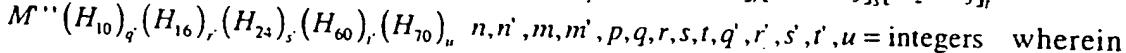
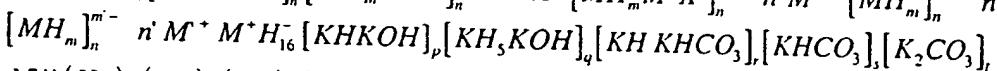
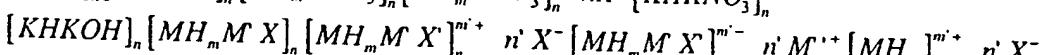
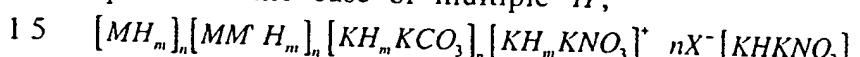
wherein  $M$ ,  $M'$ , and  $M''$  are each an alkali or alkaline earth, organic, organometallic, inorganic, or ammonium cation,  $X$  and  $X'$  are each a singly negative charged anion or a doubly negative charged anion, each integer  $n,n',m,m',p,q,r,s,t$  may be zero but not all integers may be zero, the compound contains at least one  $H$ , the monomers may be arranged in any order,  $H$  is at least one increased binding energy hydrogen

species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H$ ;



$M$ ,  $M'$ , and  $M''$  are each an alkali or alkaline earth, organic, organometallic, inorganic, or ammonium cation,  $M'''$  is other element,  $X$  and  $X'$  are a singly or doubly negative charged anion, each integer

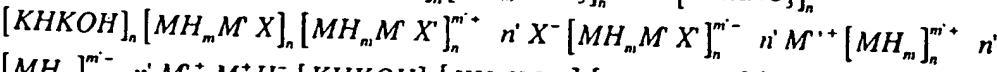
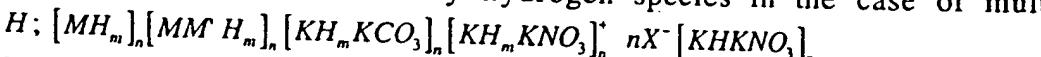
10  $n, n', m, m', p, q, r, s, t, q', r', s', t', u$  may be zero but not all integers may be zero, the compound contains at least one  $H$ , the monomers may be arranged in any order,  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H$ ;



$M$ ,  $M'$ , and  $M''$  are each an alkali or alkaline earth, organic,

20 organometallic, inorganic, or ammonium cation,  $M'''$  is an increased binding energy hydrogen compound,  $X$  and  $X'$  are a singly or doubly negative charged anion, each integer  $n, n', m, m', p, q, r, s, t, q', r', s', t', u$  may be zero but not all integers may be zero, the compound contains at least one  $H$ , the monomers may be arranged in any order,  $H$  is at least one

25 increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H$ ;  $[MH_m][MM' H_m][KH_m KCO_3][KH_m KNO_3]^+ nX^- [KHKNO_3]$



30  $M'''(H_x)_q(H_x)_r(H_y)_s(H_z)_t(H_i)_u \quad n, n', m, m', p, q, r, s, t, q', r', s', t', u = \text{integers};$

$x = \text{integer from 8 to 12}; \quad x' = \text{integer from 14 to 18}; \quad y = \text{integer from 22 to 26};$

$y' = \text{integer from 58 to 62}; \quad z = \text{integer from 68 to 72} \quad \text{wherein } M, M', \text{ and } M'' \text{ are each an alkali or alkaline earth, organic, organometallic, inorganic, or ammonium cation, } M''' \text{ is other element, } X \text{ and } X' \text{ are a singly or doubly}$

negative charged anion, each integer  $n, n', m, m', p, q, r, s, t, q', r', s', t', u$  may be zero but not all integers may be zero, the compound contains at least one  $H$ , the monomers may be arranged in any order,  $H$  is at least one increased binding energy hydrogen species, and may optionally

5 comprise at least one ordinary hydrogen species in the case of multiple  $H$ ;  $[MH_m]_n [MM' H_m]_n [KH_m KCO_3]_n [KH_m KNO_3]_n nX^- [KHKNO_3]_n$

$[KHKOH]_n [MH_m M' X]_n [MH_m M' X]^{m'+} n' X^- [MH_m M' X]^{m'-} n' M'' [MH_m]^{m'+} n' X^-$

$[MH_m]^{m'-} n' M'' M' H_{16}^- [KHKOH]_p [KH_5 KOH]_q [KH KHCO_3]_r [KHC_0_3]_s [K_2 CO_3]_t$

$M'' (H_x)_q (H_x)_r (H_y)_s (H_z)_u n, n', m, m', p, q, r, s, t, q', r', s', t', u = \text{integers};$

10  $x = \text{integer from 8 to 12}; x' = \text{integer from 14 to 18}; y = \text{integer from 22 to 26};$   
 $y' = \text{integer from 58 to 62}; z = \text{integer from 68 to 72} \text{ wherein } M, M', \text{ and } M'' \text{ are}$   
 $\text{each an alkali or alkaline earth, organic, organometallic, inorganic, or ammonium cation, } M'' \text{ is an increased binding energy hydrogen compound, } X \text{ and } X' \text{ are a singly or doubly negative charged anion, each integer}$

15  $n, n', m, m', p, q, r, s, t, q', r', s', t', u \text{ may be zero but not all integers may be zero, the compound contains at least one } H, \text{ the monomers may be arranged in any order, } H \text{ is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple } H;$

20  $[MH_m]_n [MM' H_m]_n [KH_m KCO_3]_n [KH_m KNO_3]_n nX^- [KHKNO_3]_n$

$[KHKOH]_n [MH_m M' X]_n [MH_m M' X]^{m'+} n' X^- [MH_m M' X]^{m'-} n' M'' [MH_m]^{m'+} n' X^-$

$[MH_m]^{m'-} n' M'' M' H_{16}^- [KHKOH]_p [KH_5 KOH]_q [KH KHCO_3]_r [KHC_0_3]_s [K_2 CO_3]_t$

$M'' (H_x)_q (H_x)_r (H_y)_s (H_z)_u n, n', m, m', p, q, r, s, t, q', r', s', t', u = \text{integers};$

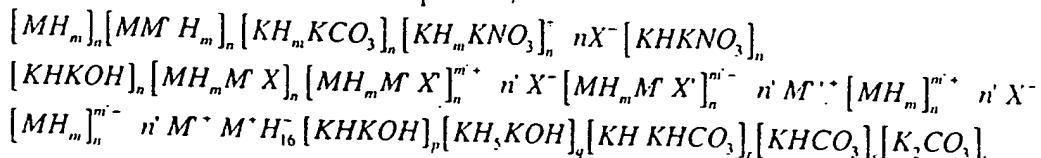
$x = \text{integer from 8 to 12}; x' = \text{integer from 14 to 18}; y = \text{integer from 22 to 26};$

25  $y' = \text{integer from 58 to 62}; z = \text{integer from 68 to 72} \text{ wherein } M, M', \text{ and } M'' \text{ are each a metal such as silicon, aluminum, Group III A elements, Group IVA elements, a transition metal, inner transition metal, tin, boron, or a rare earth, lanthanide, an alkali or alkaline earth, organic, organometallic, inorganic, or ammonium cation, } M'' \text{ is other element, } X \text{ and } X' \text{ are a}$

30  $\text{singly or doubly negative charged anion, each integer}$

$n, n', m, m', p, q, r, s, t, q', r', s', t', u \text{ may be zero but not all integers may be zero, the compound contains at least one } H, \text{ the monomers may be arranged in any order, } H \text{ is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen}$

species in the case of multiple  $H$ :



- 5       $M''(H_s)_q(H_x)_r(H_y)_t(H_z)_u$      $n, n', m, m', p, q, r, s, t, q', r', s', t', u = \text{integers};$   
        $x = \text{integer from 8 to 12}; x' = \text{integer from 14 to 18}; y = \text{integer from 22 to 26};$   
        $y' = \text{integer from 58 to 62}; z = \text{integer from 68 to 72} \text{ wherein } M, M', \text{ and } M'' \text{ are}$   
       each a metal such as silicon, aluminum, Group III A elements, Group IVA  
 10      elements, a transition metal, inner transition metal, tin, boron, or a rare  
       earth, lanthanide, an alkali or alkaline earth, organic, organometallic,  
       inorganic, or ammonium cation,  $M''$  is an increased binding energy  
       hydrogen compound,  $X$  and  $X'$  are a singly or doubly negative charged  
       anion, each integer  $n, n', m, m', p, q, r, s, t, q', r', s', t', u$  may be zero but not all  
       integers may be zero, the compound contains at least one  $H$ , the  
 15      monomers may be arranged in any order,  $H$  is at least one increased  
       binding energy hydrogen species, and may optionally comprise at least  
       one ordinary hydrogen species in the case of multiple  $H$ .

Exemplary silanes, siloxanes, and silicates that may form polymers  
 20      each have unique observed characteristics different from those of the  
       corresponding ordinary compound wherein the hydrogen content is only  
       ordinary hydrogen  $H$ . The observed characteristics which are dependent  
       on the increased binding energy of the hydrogen species include  
       stoichiometry, stability at elevated temperature, and stability in air.  
       Exemplary compounds are:

- 25       $MSiH_n$   $n = 1 \text{ to } 6$  where  $M$  is an alkali or alkaline earth cation and  $H$   
       is at least one increased binding energy hydrogen species, and may  
       optionally comprise at least one ordinary hydrogen species in the case of  
       multiple  $H$ ;  $MXSiH_n$   $n = 1 \text{ to } 5$  where  $M$  is an alkali or alkaline earth cation,  
 30       $Si$  may be replaced by  $Al, Ni$ , transition, inner transition, or rare earth  
       element,  $X$  is a singly negative charged anion or a double negative  
       charged anion, and  $H$  is at least one increased binding energy hydrogen  
       species, and may optionally comprise at least one ordinary hydrogen  
       species in the case of multiple  $H$ ;  $M_2SiH_n$   $n = 1 \text{ to } 8$  wherein  $M$  is an alkali  
 35      or alkaline earth cation (the cations may be different) and  $H$  is at least

one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H; Si_2H_n$   $n = 1 \text{ to } 8$  wherein  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H; SiH_n$   $n = 1 \text{ to } 8$  wherein  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H; Si_4n$   $n = \text{integer}$  wherein  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species;  $Si_nH_{3n}$   $n = \text{integer}$  wherein  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species;  $Si_nH_{4n}O$   $m, n = \text{integer}$  wherein  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species;  $Si_xH_{4x-y}O_y$   $x, y = \text{integer}$  wherein  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species;  $Si_xH_{4x-y}O_y$   $x, y = \text{integer}$  wherein  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species;  $Si_xH_{4x-y} \cdot H_2O$   $n = \text{integer}$  wherein  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species;  $Si_xH_{2x+2}O_y$   $x, y = \text{integer}$  wherein  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species;  $MSi_{4n}H_{10n}O_n$   $n = \text{integer}$  wherein  $M$  is an alkali or alkaline earth cation and  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species;  $MSi_{4n}H_{10n}O_{n+1}$   $n = \text{integer}$  wherein  $M$  is an alkali or alkaline earth cation and  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species;  $M_qSi_nH_mO_p$   $q, n, m, p = \text{integer}$  wherein  $M$  is an alkali or alkaline earth cation and  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H; M_qSi_nH_m$   $q, n, m = \text{integer}$  wherein  $M$  is an alkali or alkaline earth cation and  $H$  is at least one increased binding energy hydrogen species.

hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H; Si_nH_mO_p$ ,  $n,m,p = \text{integer}$  wherein  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H; Si_nH_m$ ,  $n,m = \text{integer}$  wherein  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H; SiO_2H_n$ ,  $n = 1 \text{ to } 6$  wherein  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H; MSiO_2H_n$ ,  $n = 1 \text{ to } 6$  wherein  $M$  is an alkali or alkaline earth cation and  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H; MSi_2H_n$ ,  $n = 1 \text{ to } 14$  wherein  $M$  is an alkali or alkaline earth cation and  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H; M_2SiH_n$ ,  $n = 1 \text{ to } 8$  wherein  $M$  is an alkali or alkaline earth cation and  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H$ ; and polyalkylsiloxane wherein  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H; Si_xH_y(H_{16})_z$ ,  $x = \text{integer}$ ;  $y = \text{integer from } 2x + 2 \text{ to } 4x$ ;  $z = \text{integer}$  wherein  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species.

Examples of the singly negative charged anions disclosed herein include but are not limited to halogen ions, hydroxide ion, hydrogen carbonate ion, and nitrate ion. Examples of the doubly negative charged anions disclosed herein include but are not limited to carbonate ion, 30 oxides, phosphates, hydrogen phosphates, and sulfate ion.

Preferred metals  $M$  of increased binding energy hydrogen compounds having a formulae such as  $MH_n$ ,  $n = 1 \text{ to } 8$  wherein  $H$  is at least one increased binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species in the case of multiple  $H$  include the Group VIB ( $Cr, Mo, W$ ) and Group IB ( $Cu, Ag, Au$ ) elements. The compounds are useful for purification of the metals. The

purification is achieved via formation of the increased binding energy hydrogen compounds that have a high vapor pressure. Each compound is isolated by cryopumping.

In an embodiment of a superconductor of reduced dimensionality 5 of the present invention, at least one increased binding energy hydrogen species, and optionally at least one ordinary hydrogen species, is reacted with or bonded to a source of electrons. The source of electrons may be any positively charged other element such as any atom of the periodic chart such as an alkali, alkaline earth, transition metal, inner transition 10 metal, rare earth, lanthanide, or actinide cation to form a structure described by a lattice described in '99 Mills GUT (pages 270-289 which are incorporated by reference). Exemplary superconductors can be formulated from an increased binding energy hydrogen polymer, an inorganic increased binding energy hydrogen polymer, a metal hydrino 15 hydride polymer, an alkali-transition metal hydrino hydride polymer, and a compound comprising a neutral, positive, or negative polymer of increased binding energy hydrogen species.

A xerographic toner may comprise an increased binding energy hydrogen compound. The toner may be a mixture of an increased 20 binding energy hydrogen compound and at least one additional compound or material such as a carbon compound. Increased binding energy hydrogen compounds that have one or more of the following properties, 1.) readily form stable charge ions, 2.) form highly charged ions, 3.) attach to carrier particles, and 4.) bind to a substrate such as 25 paper are preferred toner compounds. Exemplary ions and compounds are polyhydrogen ions such as  $NaH_{70}H_{23}^{3+}$ ,  $OH_{23}^+$ ,  $H_{16}^-$ , and silanes which may form positive or negative ions such as  $Si_xH_y(H_{16})_z$ ,  $x = \text{integer}$ ;  $y = \text{integer from } 2x+2 \text{ to } 4x$ ;  $z = \text{integer}$  wherein  $H$  is at least one increased 30 binding energy hydrogen species, and may optionally comprise at least one ordinary hydrogen species.

Magnetic increased binding energy hydrogen compounds such as metal hydrino hydrides, alkali-transition metal hydrino hydrides, and polyhydrogen compounds may be useful as magnets, magnetic materials, or may comprise a magnetic computer memory storage material to coat 35 a floppy disk for example. The compound may have the formula  $MH_n$  wherein  $n$  is an integer from 1 to 6,  $M$  is a transition element, an inner

transition element, a rare earth element, or Ni, and the hydrogen content  $H_n$  of the compound comprises at least one increased binding energy hydrogen species. The compound may have the formula  $MNiH_n$  wherein n is an integer from 1 to 6, M is an alkali cation, alkaline earth cation,

5 silicon, or aluminum, and the hydrogen content  $H_n$  of the compound comprises at least one increased binding energy hydrogen species. The compound may have the formula  $MM'H_n$  wherein n is an integer from 1 to 6, M is an alkali cation, alkaline earth cation, silicon, or aluminum, M' is a transition element, inner transition element, or a rare earth element

10 cation, and the hydrogen content  $H_n$  of the compound. The compound may have the formula  $M(H_{10})_q(H_{16})_r(H_{24})_s(H_{60})_t(H_{70})_u$  wherein q, r, s, t, and u are each an integer including zero but not all zero, M is other element such as any atom, molecule, or compound, and the hydrogen content  $(H_{10})_q(H_{16})_r(H_{24})_s(H_{60})_t(H_{70})_u$  of the compound comprises at least one

15 increased binding energy hydrogen species. The compound may have the formula  $M(H_{10})_q(H_{16})_r(H_{24})_s(H_{60})_t(H_{70})_u$  wherein q, r, s, t, and u are each an integer including zero but not all zero, M is an increased binding energy hydrogen compound, and the hydrogen content  $(H_{10})_q(H_{16})_r(H_{24})_s(H_{60})_t(H_{70})_u$  of the compound comprises at least one

20 increased binding energy hydrogen species.

Increased binding energy hydrogen compounds comprising a desired element may be synthesized by placing the element in the gas cell hydrino hydride reactor. The element may be a foil. For example, gold hydrino hydride may be synthesized by placing a gold foil or gold containing substrate into a gas cell such as a gas cell comprising a titanium dissociator and a  $KI$  or  $KBr$  catalyst. The gold hydrino hydride film that forms may be analyzed by TOFSIMS. Magnetic compounds such as nickel, cobalt, or samarium hydrino hydride may be synthesized by placing foils of these elements in a gas cell hydrino hydride reactor. These metal hydrino hydrides may be useful as magnets, magnetic materials, as computer memory storage materials, or wherever magnetic properties are desired. Actinide, lanthanide, silanes, and semiconductor hydrino hydride compounds may be synthesized by placing the reactant actinides, lanthanides, silicon, and semiconductors such as gallium in the

gas cell hydrino hydride reactor. The products may be collected from the cell, purified, and analyzed by TOFSIMS.

### 3. METHOD OF ISOTOPE SEPARATION

5       The selectivity of hydrino atoms and hydride ions to form bonds with specific isotopes based on a differential in bond energy provides a means to purify desired isotopes of elements such as  $^{235}_{92}U$  and  $^{239}_{94}Pu$ . The term isotope as used herein refers to any isotope given in the CRC which is herein incorporated by reference [R. C. Weast, Editor, CRC Handbook of  
10 Chemistry and Physics, 58th Edition, CRC Press, (1977), pp., B-270-B-354]. Differential bond energy can arise from a difference in the nuclear moments of the isotopes, and with a sufficient difference they can be separated.

15      A method of isotope separation comprises the step of reacting an element or compound having an isotopic mixture containing the desired element with an increased binding energy hydrogen species in atomic percent shortage based on the stoichiometric amount to fully react with the desired isotope. The increased binding energy hydrogen species is selected such that the bond energy of the reaction product is dependent  
20     on the isotope of the desired element. Thus, an increased binding energy species can be selected such that the predominant reaction product contains at least one increased binding energy hydrogen species bound to the desired isotope. The compound comprising at least one increased binding energy hydrogen species and the desired isotope can  
25     be separated from the reaction mixture. The increased binding energy hydrogen species may be separated from the desired isotope to obtain the desired isotope. The recovered isotope may be reacted with the increased binding energy hydrogen species and these steps may be repeated to obtain a desired level of enrichment. The use of the term  
30     "isotope" in this context includes an individual element as well as compounds containing the desired elemental isotope.

35      A method of isotope separation comprises the step of reacting an element or compound having an isotopic mixture containing the desired element with an increased binding energy hydrogen species to bond with the undesired isotope. Since the bond energy of the reaction product is dependent on the isotope of the undesired element, an

increased binding energy species can be selected such that the predominant reaction product contains at least one increased binding energy hydrogen species bound to the undesired isotope, and the desired isotope remains substantially unbound. The compound  
5 comprising at least one increased binding energy hydrogen species and the undesired isotope can be separated from the reaction mixture to obtain the desired isotope. If less than a stoichiometric amount of increased binding energy hydrogen is used, these steps may be repeated until the desired level of enrichment is obtained. The use of  
10 the term "isotope" in this context includes an individual element as well as compounds containing the desired elemental isotope.

A method of isotope separation comprises the step of reacting an element or compound having an isotopic mixture containing the desired element with an increased binding energy hydrogen species in atomic  
15 percent shortage based on the stoichiometric amount to fully react with the undesired isotope. Since the bond energy of the reaction product is dependent on the isotope of the undesired element, an increased binding energy species can be selected such that the predominant reaction product contains at least one increased binding energy  
20 hydrogen species bound to the undesired isotope, and the desired isotope remains substantially unbound. The compound comprising at least one increased binding energy hydrogen species and the undesired isotope can be separated from the reaction mixture to obtain the desired isotope. The recovered enriched desired isotope may be reacted  
25 with the increased binding energy hydrogen species and these steps may be repeated to obtain a desired level of enrichment. The use of the term "isotope" in this context includes an individual element as well as compounds containing the desired elemental isotope.

Sources of reactant increased binding energy hydrogen species  
30 include the electrolytic cell, gas cell, gas discharge cell, and plasma torch cell hydride reactors of the present invention and increased binding energy hydrogen compounds. The increased binding energy hydrogen species may be an increased binding energy hydride ion. The compound comprising at least one increased binding energy hydrogen species and the desired isotopically enriched element can be separated by any conventional method. In a further embodiment, the compound  
35

can be reacted to form a different compound. The increased binding energy hydrogen species can be separated from the desired isotope or compound containing the isotope, for example, by a decomposition reaction such as a plasma discharge or plasma torch reaction or  
5 displacement reaction of the increased binding energy hydrogen species.

For example, a hydrino hydride electrolytic cell can be operated with a  $K_2CO_3$  catalyst. Increased binding energy hydrogen compounds such as  $KHK^{17}OH$  and  $KHK^{18}OH$  form preferentially. The electrolyte  
10 comprising a mixture of catalyst,  $KHK^{17}OH$ , and  $KHK^{18}OH$  may be concentrated and  $KHK^{17}OH$  and  $KHK^{18}OH$  allowed to precipitate to yield compounds which are isotopically enriched in  $^{17}O$  or  $^{18}O$ , compared to  $^{16}O$ .

Another method to obtain  $^{17}O$  and  $^{18}O$  comprises reacting a  
15 hydrino hydride compound such as  $KH,I$  with a source of oxygen such as water to form  $KHKOH$  which is enriched in  $^{17}O$  and  $^{18}O$ . The desired oxygen isotope may be collected as oxygen gas by decomposing the  $KHKOH$  by methods such as thermal decomposition.

For example, a hydrino hydride electrolytic cell can be operated  
20 with a  $K_2CO_3$  catalyst. Increased binding energy hydrogen compounds such as  $KHK^{17}OH$  and  $KHK^{18}OH$  form preferentially. The electrolyte comprising a mixture of catalyst,  $KHK^{17}OH$ , and  $KHK^{18}OH$  may be concentrated and  $KHK^{17}OH$  and  $KHK^{18}OH$  allowed to precipitate to yield compounds in which are isotopically enriched in  $^{16}O$ .

25 Differential bond energy can arise from a difference in the nuclear moments of the isotopes and/or a difference in masses of the isotopes, and with a sufficient difference they can be separated. This mechanism can be enhanced as the temperature is reduced. Thus, separation can be enhanced by forming the increased binding energy compounds and  
30 performing the separation at lower temperatures.

The mass of tritium is the largest of any hydrogen isotope, and the nuclear magnetic moment is the largest. Thus, the electrolyte of a  $K_2CO_3/D_2O$  cell may become enriched in tritium compounds during  
35 electrolysis due to selective bonding of the tritium isotope to form hydrino hydride compounds. These compounds may be isolated and decomposed to release tritium.

### 3. EXPERIMENTAL

#### 3.1 Synthesis and Isolation of Inorganic Hydrogen Polymer Compounds

5

##### 3.1.1 Electrolytic Cell Hydrino Hydride Reactor

An electrolytic cell hydride reactor of the present invention is shown in FIGURE 1. An electric current is passed through an electrolytic solution 102 contained in vessel 101 by the application of a voltage. The 10 voltage is applied to an anode 104 and cathode 106 by a power controller 108 powered by a power supply 110. The electrolytic solution 102 contains a catalyst for producing hydrino atoms.

According to one embodiment of the electrolytic cell hydride reactor, cathode 106 is formed of nickel cathode 106 and anode 104 is 15 formed of platinized titanium or nickel. The electrolytic solution 102 comprising an about 0.5M aqueous  $K_2CO_3$  electrolytic solution ( $K^+ / K^+$  catalyst) is electrolyzed. The cell is operated within a voltage range of 1.4 to 3 volts. In one embodiment of the invention, the electrolytic solution 102 is molten.

20

Hydrino atoms form at the cathode 106 via contact of the catalyst of electrolyte 102 with the hydrogen atoms generated at the cathode 106. The electrolytic cell hydride reactor apparatus further comprises a source of electrons in contact with the hydrinos generated in the cell, to 25 form hydrino hydride ions. The hydrinos are reduced (i.e. gain the electron) in the electrolytic cell to hydrino hydride ions. Reduction occurs by contacting the hydrinos with any of the following: 1.) the cathode 106, 2.) a reductant which comprises the cell vessel 101, or 3.) any of the reactor's components such as features designated as anode 104 or electrolyte 102, or 4.) a reductant 160 extraneous to the 30 operation of the cell (i.e. a consumable reductant added to the cell from an outside source). Any of these reductants may comprise an electron source for reducing hydrinos to hydrino hydride ions.

35

A compound may form in the electrolytic cell between the hydrino hydride ions and cations. The cations may comprise, for example, any of the cations described herein, in particular an oxidized species of the

material of the cathode or anode, a cation of an added reductant, or a cation of the electrolyte (such as a cation comprising the catalyst).

Inorganic hydrogen polymer compounds were prepared during the electrolysis of an aqueous solution of  $K_2CO_3$  corresponding to the catalyst

5       $K^+ / K^{+}$ . The cell comprised a 10 gallon (33 in. x 15 in.) Nalgene tank (Model # 54100-0010). Two 4 inch long by 1/2 inch diameter terminal bolts were secured in the lid, and a cord for a calibration heater was inserted through the lid. The cell assembly is shown in FIGURE 1.

10     The cathode comprised 1.) a 5 gallon polyethylene bucket which served as a perforated (mesh) support structure where 0.5 inch holes were drilled over all surfaces at 0.75 inch spacings of the hole centers and 2.) 5000 meters of 0.5 mm diameter clean, cold drawn nickel wire (NI 200 0.0197", HTN36NOAG1, A1 Wire Tech, Inc.). The wire was wound uniformly around the outside of the mesh support as 150  
15     sections of 33 meter length. The ends of each of the 150 sections were spun to form three cables of 50 sections per cable. The cables were pressed in a terminal connector which was bolted to the cathode terminal post. The connection was covered with epoxy to prevent corrosion.

20     The anode comprised an array of 15 platinized titanium anodes (10 - Engelhard Pt/Ti mesh 1.6" x 8" with one 3/4" by 7" stem attached to the 1.6" side plated with 100 U series 3000; and 5 - Engelhard 1" diameter x 8" length titanium tubes with one 3/4" x 7" stem affixed to the interior of one end and plated with 100 U Pt series 3000). A 3/4" wide tab was made at the end of the stem of each anode by bending it at a right angle to the anode. A 1/4" hole was drilled in the center of each tab. The tabs were bolted to a 12.25" diameter polyethylene disk (Rubbermaid Model #JN2-2669) equidistantly around the circumference. Thus, an array was fabricated having the 15 anodes  
25     suspended from the disk. The anodes were bolted with 1/4" polyethylene bolts. Sandwiched between each anode tab and the disk was a flattened nickel cylinder also bolted to the tab and the disk. The cylinder was made from a 7.5 cm by 9 cm long x 0.125 mm thick nickel foil. The cylinder traversed the disk and the other end of each was  
30     pressed about a 10 AWG/600 V copper wire. The connection was sealed with shrink tubing and epoxy. The wires were pressed into two  
35

terminal connectors and bolted to the anode terminal. The connection was covered with epoxy to prevent corrosion.

Before assembly, the anode array was cleaned in 3 M *HCl* for 5 minutes and rinsed with distilled water. The cathode was cleaned by placing it in a tank of 0.57 M  $K_2CO_3$ /3%  $H_2O_2$  for 6 hours and then rinsing it with distilled water. The anode was placed in the support between the central and outer cathodes, and the electrode assembly was placed in the tank containing electrolyte. The power supply was connected to the terminals with battery cables.

The electrolyte solution comprised 28 liters of 0.57 M  $K_2CO_3$  (Alfa  $K_2CO_3$ , 99±%).

The calibration heater comprised a 57.6 ohm 1000 watt Incolloy 800 jacketed Nichrome heater which was suspended from the polyethylene disk of the anode array. It was powered by an Invar constant power (± 0.1% supply (Model #TP 36-18). The voltage (± 0.1%) and current (± 0.1%) were recorded with a Fluke 8600A digital multimeter.

Electrolysis was performed at 20 amps constant current with a constant current (± 0.02%) power supply (Kepco Model # ATE 6 - 100M).

The voltage (± 0.1%) was recorded with a Fluke 8600A digital multimeter. The current (± 0.5%) was read from an Ohio Semitronics CTA 101 current transducer.

The temperature (± 0.1 °C) was recorded with a microprocessor thermometer Omega HH21 using a type K thermocouple which was inserted through a 1/4" hole in the tank lid and anode array disk. To eliminate the possibility that temperature gradients were present, the temperature was measured throughout the tank. No position variation was found to within the detection of the thermocouple (± 0.1 °C).

The temperature rise above ambient ( $\Delta T = T(\text{electrolysis only}) - T(\text{blank})$ ) and electrolysis power were recorded daily. The heating coefficient was determined "on the fly" by turning an internal resistance heater off and on, and inferring the cell constant from the difference between the losses with and without the heater. 20 watts of heater power were added to the electrolytic cell every 72 hours

where 24 hours was allowed for steady state to be achieved. The temperature rise above ambient ( $\Delta T_2 = T(\text{electrolysis + heater}) - T(\text{blank})$ ) was recorded as well as the electrolysis power and heater power.

In all temperature measurements, the "blank" comprised 28 liters  
5 of water in a 10 gallon (33" x 15") Nalgene tank with lid (Model #54100-0010). The stirrer comprised a 1 cm diameter by 43 cm long glass rod to which an 0.8 cm by 2.5 cm Teflon half moon paddle was fastened at one end. The other end was connected to a variable speed stirring motor (Talboys Instrument Corporation Model # 1075C). The stirring rod was  
10 rotated at 250 RPM.

The "blank" (nonelectrolysis cell) was stirred to simulate stirring in the electrolytic cell due to gas sparging. The one watt of heat from stirring resulted in the blank cell operating at 0.2 °C above ambient.

The temperature ( $\pm 0.1$  °C) of the "blank" was recorded with a  
15 microprocessor thermometer (Omega HH21 Series) which was inserted through a 1/4" hole in the tank lid.

A cell that produced  $6.3 \times 10^8$  J of enthalpy of formation of increased binding energy hydrogen compounds was operated by BlackLight Power, Inc. (Malvern, PA), hereinafter "BLP Electrolytic Cell".  
20 The cell was equivalent to that described herein. The cell description is also given by Mills et al. [R. Mills, W. Good, and R. Shaubach, Fusion Technol. 25, 103 (1994)] except that it lacked the additional central cathode.

Thermacore Inc. (Lancaster, PA) operated an electrolytic cell  
25 described by Mills et al. [R. Mills, W. Good, and R. Shaubach, Fusion Technol. 25, 103 (1994)] herein after "Thermacore Electrolytic Cell". This cell had produced an enthalpy of formation of increased binding energy hydrogen compounds of  $1.6 \times 10^9$  J that exceeded the total input enthalpy given by the product of the electrolysis voltage and current over time by  
30 a factor greater than 8.

Idaho National Engineering Laboratory (INEL) operated [Jacox, M. G., Watts, K. D., "The Search for Excess Heat in the Mills Electrolytic Cell", Idaho National Engineering Laboratory, EG&G Idaho, Inc., Idaho Falls, Idaho, 83415, January 7, 1993] a cell, hereinafter "INEL Electrolytic Cell",  
35 identical to the Thermacore Electrolytic Cell except that it was minus the central cathode and that the cell was wrapped in a one-inch layer of

urethane foam insulation about the cylindrical surface. The cell was operated in a pulsed power mode. A current of 10 amperes was passed through the cell for 0.2 seconds followed by 0.8 seconds of zero current for the current cycle. The cell voltage was about 2.4 volts, for an  
5 average input power of 4.8 W. The electrolysis power average was 1.84 W, and the stirrer power was measured to be 0.3 W. Thus, the total average net input power was 2.14 W. The cell was operated at various resistance heater settings, and the temperature difference between the cell and the ambient as well as the heater power were measured. The  
10 results of the excess power as a function of cell temperature with the cell operating in the pulsed power mode at 1 Hz with a cell voltage of 2.4 volts, a peak current of 10 amperes, and a duty cycle of 20 % showed that the excess power is temperature dependent for pulsed power operation, and the maximum excess power was 18 W for an input  
15 electrolysis joule heating power of 2.14 W. Thus, the ratio of excess power to input electrolysis joule heating power was 850 %.

### 3.1.2 Quartz Gas Cell Hydrino Hydride Reactor

20 Hydrino hydride compounds were prepared in a vapor phase gas cell with a tungsten filament and *KI* as the catalyst according to Eqs. (3-5) and the reduction to hydrino hydride ion (Eq. (11)) occurred in the gas phase. The high temperature experimental gas cell shown in FIGURE 2 was used to produce hydrino hydride compounds. Hydrino atoms  
25 were formed by hydrogen catalysis using potassium ions and hydrogen atoms in the gas phase.

The experimental gas cell hydrino hydride reactor shown in FIGURE 2 comprised a quartz cell in the form of a quartz tube 2 five hundred (500) millimeters in length and fifty (50) millimeters in diameter. The quartz cell formed a reaction vessel. One end of the cell was necked down and attached to a fifty (50) cubic centimeter catalyst reservoir 3. The other end of the cell was fitted with a Conflat style high vacuum flange that was mated to a Pyrex cap 5 with an identical Conflat style flange. A high vacuum seal was maintained with a Viton O-ring and stainless steel clamp. The Pyrex cap 5 included five glass-to-metal tubes for the attachment of a gas inlet line 25 and gas outlet line 21, two

inlets 22 and 24 for electrical leads 6, and a port 23 for a lifting rod 26. One end of the pair of electrical leads was connected to a tungsten filament 1. The other end was connected to a Sorensen DCS 80-13 power supply 9 controlled by a custom built constant power controller. Lifting rod 26 was adapted to lift a quartz plug 4 separating the catalyst reservoir 3 from the reaction vessel of cell 2. Optionally, the reactor further comprised a thermal radiation shield at the top of the cell to provide further insulation.

H<sub>2</sub> gas was supplied to the cell through the inlet 25 from a compressed gas cylinder of ultra high purity hydrogen 11 controlled by hydrogen control valve 13. Helium gas was supplied to the cell through the same inlet 25 from a compressed gas cylinder of ultrahigh purity helium 12 controlled by helium control valve 15. The flow of helium and hydrogen to the cell is further controlled by mass flow controller 10, mass flow controller valve 30, inlet valve 29, and mass flow controller bypass valve 31. Valve 31 was closed during filling of the cell. Excess gas was removed through the gas outlet 21 by a molecular drag pump 8 capable of reaching pressures of 10<sup>-4</sup> torr controlled by vacuum pump valve 27 and outlet valve 28. Pressures were measured by a 0-1000 torr Baratron pressure gauge and a 0-100 torr Baratron pressure gauge 7. The filament 1 was 0.381 millimeters in diameter and two hundred (200) centimeters in length. The filament was suspended on a ceramic support to maintain its shape when heated. The filament was resistively heated using power supply 9. The power supply was capable of delivering a constant power to the filament. The catalyst reservoir 3 was heated independently using a band heater 20, also powered by a constant power supply. The entire quartz cell was enclosed inside an insulation package comprised of Zircar AL-30 insulation 14. Several K type thermocouples were placed in the insulation to measure key temperatures of the cell and insulation. The thermocouples were read with a multichannel computer data acquisition system.

The cell was operated under flow conditions with a total pressure of less than two (2) torr of hydrogen or control helium via mass flow controller 10. The filament was heated to a temperature in the range from 1000-2000°C as calculated by its resistance. A preferred temperature was about 1400 °C. This created a "hot zone" within the

quartz tube of about 700-800 °C as well as causing atomization of the hydrogen gas. The catalyst reservoir was heated to a temperature of 700 °C to establish the vapor pressure of the catalyst. The quartz plug 4 separating the catalyst reservoir 3 from the reaction vessel 2 was 5 removed using the lifting rod 26 which was slid about 2 cm through the port 23. This introduced the vaporized catalyst into the "hot zone" containing the atomic hydrogen, and allowed the catalytic reaction to occur.

As described above, a number of thermocouples were positioned to 10 measure the linear temperature gradient in the outside insulation. The gradient was measured for several known input powers over the experimental range with the catalyst valve closed. Helium supplied from the tank 12 and controlled by the valves 15, 29, 30, and 31, and flow controller 10 was flowed through the cell during the calibration 15 where the helium pressure and flow rates were identical to those of hydrogen in the experimental cases. The thermal gradient was determined to be linearly proportional to input power. Comparing an experimental gradient (catalyst valve open/hydrogen flowing) to the calibration gradient allowed the determination of the requisite power to 20 generate that gradient. In this way, calorimetry was performed on the cell to measure the heat output with a known input power. The data was recorded with a Macintosh based computer data acquisition system (PowerComputing PowerCenter Pro 180) and a National Instruments, Inc. NI-DAQ PCI-MIO-16XE-50 Data Acquisition Board.

Enthalpy of catalysis from the gas energy cell having a gaseous transition catalyst ( $K^+ / K^+$ ) was observed with low pressure hydrogen in the presence of potassium iodide ( $KI$ ) which was volatilized at the operating temperature of the cell. The enthalpy of formation of increased binding energy hydrogen compounds resulted in a steady 25 state power of about 15 watts that was observed from the quartz reaction vessel containing about 200 mtorr of  $KI$  when hydrogen was flowed over the hot tungsten filament. However, no excess enthalpy was 30 observed when helium was flowed over the hot tungsten filament or when hydrogen was flowed over the hot tungsten filament with no  $KI$  35 present in the cell.

In a separate experiment  $RbI$  or  $RbCl$  replaced  $KI$  as the gaseous transition catalyst according to Eq.(6), Eq.(7), and Eq.(8).

- In two other embodiments, the experimental gas cell hydrino hydride reactor shown in FIGURE 2 comprised a titanium screen filament of six titanium screen strips 3 cm wide and 30 cm in length or an 8 meter long coil of a three stand cable of 0.38 mm diameter nickel wire (99+% Alpha #10249) which replaced the tungsten filament 1. The titanium screen filament or nickel coil filament dissociator was treated with 0.6 M  $K_2CO_3$ /10%  $H_2O_2$  before being used in the quartz cell. The filament was suspended on  $Al_2O_3$  cylindrical filament supports. The cell was operated at 800 °C when the filament temperature was from 1000 to 1200 °C, and  $KBr$  or  $KI$  catalyst was vaporized into the gas cell by heating the catalyst reservoir. Hydrogen was flowed through the cell at a steady state pressure of 1 torr.
- In two other embodiments, a second 30 cm wide and 30 cm long nickel or titanium screen dissociator was wrapped inside the inner wall of the cell. The screen was heated by the titanium screen or nickel coil filament.
- In another embodiment, the experimental gas cell hydrino hydride reactor shown in FIGURE 2 comprised a Ni fiber mat (30.2 g, Fibrex from National Standard) inserted into the inside the quartz cell 2. The Ni mat was used as the  $H_2$  dissociator which replaced the tungsten filament 1. The cell 2 and the catalyst reservoir 3 were each independently encased by split type clam shell furnaces (The Mellen Company) which replaced the Zircar AL-30 insulation 14 and were capable of operating up to 1200 °C. The cell and catalyst reservoir were heated independently with their heaters to independently control the catalyst vapor pressure and the reaction temperature. The  $H_2$  pressure was maintained at 2 torr at a flow rate of  $\frac{0.5\text{ cm}^3}{\text{min}}$ . The Ni mat was maintained at 900 °C, and the  $KI$  catalyst was maintained at 700 °C for 100 h.

### 3.1.3 Concentric Quartz Tubes Gas Cell Hydrino Hydride Reactor

- Hydrino hydride compounds were prepared in a concentric quartz tubes gas cell hydrino hydride reactor comprising a Ni screen dissociator

and *KI* as the catalyst. The experimental concentric quartz tubes gas cell hydrino hydride reactor is shown in FIGURE 3. The reactor cell comprised two concentric quartz tubes 401 and 402 of dimensions 1" OD X 21" long and 3/4" OD X 24" long, respectively. The 1" OD tube was closed at the bottom end with a thermowell 403 and the 3/4" OD tube was open at both ends. The quartz tubes were connected to Swagelok fittings 404 and 405 to provide a system capable of maintaining a vacuum. Two sets of external heaters 406 and 407 were used to control the temperature of the catalyst and the Ni fiber dissociator independently. The heaters comprised Chrome Aluminum Iron heating elements imbedded in a high purity  $Al_2O_3$  cement (The Mellen Company).

A Ni fiber mat dissociator -30.2 g (National Standard Company) 408 was placed in the 3/4" quartz tube 402. The Ni mat was pretreated in the cell by flowing  $H_2$  (Scientific Grade- MGS Industries) from a  $H_2$  source 409 at a rate of 20 cm<sup>3</sup>/min at a temperature of 900 °C for 24 h. The system was cooled by flowing He (Scientific Grade- MGS Industries) from a helium source 410 for 12 hours. *KI* catalyst - 10.3 g (99.0%, Alfa Aesar) 411 was placed at the bottom of the 1" OD quartz tube 401.  $H_2$  was introduced in the annular space 412 of the two concentric tubes and the product gas was pumped away via the 3/4" quartz tube using a vacuum pump 413. The total pressure was maintained at 2.0 torr. The Ni dissociator temperature was maintained around 950 °C (measured by a Type C thermocouple 414), and the catalyst temperature was maintained around 650°C (measured by a Type C thermocouple 415). The reaction was stopped after 170 h, and the reactor was cooled in He for 12 hours before exposing the cell to atmospheric conditions.

### 3.1.4 Stainless Steel Gas Cell Hydrino Hydride Reactor

Hydrino hydride compounds were prepared in a stainless steel gas cell hydrino hydride reactor comprising a Ti screen dissociator and *KI* as the catalyst. The experimental stainless steel gas cell hydrino hydride reactor is shown in FIGURE 4. It comprised a 304-stainless steel cell 301 in the form of a tube having an internal cavity 317 having dimensions of 359 millimeters in length and 73 millimeters in diameter. The top end of the cell was welded to a high vacuum 4 5/8 inch bored through conflat

flange 318. The mating blank conflat flange 319 contained a single coaxial hole in which was welded a 1/4 inch diameter stainless steel tube 302 that was 100 cm in length. A silver plated copper gasket was placed between the two flanges. The two flanges are held together with 10 circumferential bolts. The bottom of the 1/4 inch tube 302 was flush with the bottom surface of the top flange 319. The tube 302 provided a passage for air to be removed from the cell and hydrogen to be supplied to the cell. The cell 301 was surrounded by four heaters 303, 304, 305, and 306. Concentric to the heaters was high temperature AL 30 Zircar insulation 307. Each of the four heaters were individually thermostatically controlled.

Titanium screen was used as the dissociator and as a reactant to produce titanium hydrino hydride. The cylindrical wall of the cell 301 was lined with two layers of Ti screen 308. Before placing the titanium dissociator in the cell 301. The titanium was reacted with an aqueous solution of 0.57 M  $K_2CO_3$  and 3%  $H_2O_2$  for ten minutes. The titanium screen was removed from the solution, and the reaction product was allowed to dry on the screen at room temperature. The screen was then baked at 200 °C for 12 hours. 71 grams of powdered KI 309 was poured into the cell 301. The cell was sealed then continuously evacuated with a high vacuum turbo pump 310. The pressure gauge (Varian Convector, Pirrani type) 312 read 50 millitorr. The cell was heated by supplying power to the heaters 303, 304, 305, and 306. The power of the largest heater 305 was measured using a Clarke -Hess model 259 wattmeter. Its 0 to 1 V analog output was fed to the DAS and recorded with the other signals. The temperature of the cell read with an Omega type K thermocouple with a type 97000 controller was then slowly increased over 2 hours to 300 °C. The pressure initially increased, then slowly dropped to 10 millitorr. The vacuum pump valve 311 was closed. Hydrogen was supplied from tank 316 through regulator 315 to the valve 314. Hydrogen was slowly added by first filling the tube between valve 314 and valve 313 to 800 torr. Valve 313 was slowly opened to transfer the trapped hydrogen to the cell 301. This hydrogen transfer method was repeated until the pressure in the reactor climbed to 760 torr. The temperature of the cell was then slowly increased to 650 °C over 5 hours. The hydrogen valve 313 was closed. For the next two

hours, the vacuum valve 311 was slowly partially opened to bleed off the surplus hydrogen to maintain a pressure between 400 to 500 millitorr. During the next 17 hours the pressure climbed to 1 torr. The cell was then cooled and opened. About 5 grams of blue crystals were  
5 observed to have formed in the bottom of the cell.

### 3.2 Novel Inorganic Hydride from a Potassium Carbonate Electrolytic Cell

#### 10 ABSTRACT

A novel inorganic hydride compound  $KH\text{KHCO}_3$ , which is stable in water and comprises a high binding energy hydride ion was isolated following the electrolysis of a  $K_2\text{CO}_3$  electrolyte. Inorganic hydride clusters  
15  $K[\text{KH}\text{KHCO}_3]_n^+$  were identified by Time of Flight Secondary Ion Mass Spectroscopy. Moreover, the existence of a novel hydride ion has been determined using X-ray photoelectron spectroscopy, and proton nuclear magnetic resonance spectroscopy. Hydride ions with increased binding energies may be the basis of a high voltage battery for electric vehicles.  
20

#### INTRODUCTION

Evidence of the changing landscape for automobiles can be found in the recent increase in research into the next generation of automobiles.  
25 But, the fact that there is no clear front-runner in the technological race to replace the internal combustion (IC) engine can be attested to by the divergent approaches taken by the major automobile companies. Programs include various approaches to hybrid vehicles, alternative fueled vehicles such as dual-fired engines that can run on gasoline or  
30 compressed natural gas, and a natural gas-fired engine. Serious efforts are also being put into a number of alternative fuels such as ethanol, methanol, propane, and reformulated gasoline. To date, the most favored approach is an electric vehicle based on fuel cell technology or advanced battery technology such as sodium nickel chloride, nickel-metal hydride, and lithium-ion batteries [I. Uehara, T. Sakai, H. Ishikawa, J. Alloy Comp.,  
35 253/254, (1997), pp. 635-641]. Although billions of dollars are being

spent to develop an alternative to the IC engine, there is no technology in sight that can match the specifications of IC engine system [New Scientist, April 15, (1995) pp. 32-35].

Fuel cells are attractive over the IC engine because they convert  
5 hydrogen to water at about 70% efficiency when running at about 20%  
below peak output [D. Mulholland, Defense News, "Powering the Future  
Military", March 8, 1999, pp. 1&34]. But, hydrogen is difficult and  
dangerous to store. Cryogenic, compressed gas, and metal hydride  
storage are the main options. In the case of cryogenic storage,  
10 liquefaction of hydrogen requires an amount of electricity which is at  
least 30% of the lower heating value of liquid hydrogen [S. M. Aceves, G.  
D. Berry, and G. D. Rambach, Int. J. Hydrogen Energy, Vol. 23, No. 7,  
(1998), pp. 583-591]. Compressed hydrogen, and metal hydride storage  
are less viable since the former requires an unacceptable volume, and the  
15 latter is heavy and has difficulties supplying hydrogen to match a load  
such as a fuel cell [S. M. Aceves, G. D. Berry, and G. D. Rambach, Int. J.  
Hydrogen Energy, Vol. 23, No. 7, (1998), pp. 583-591]. The main  
challenge with hydrogen as a replacement to gasoline is that a hydrogen  
production and refueling infrastructure would have to be built.  
20 Hydrogen may be obtained by reforming fossil fuels. However, in  
practice fuel cell vehicles would probably achieve only 10 to 45 percent  
efficiency because the process of reforming fossil fuel into hydrogen and  
carbon dioxide requires energy [D. Mulholland, Defense News, "Powering  
the Future Military", March 8, 1999, pp. 1&34]. Presently, fuel cells are  
25 also impractical due to their high cost as well as the lack of inexpensive  
reforming technology [J. Ball, The Wall Street Journal, "Auto Makers Are  
Racing to Market "Green" Cars Powered by Fuel Cells", March 15, 1999, p.  
1].

In contrast, batteries are attractive because they can be recharged  
30 wherever electricity exists which is ubiquitous. The cost of mobile  
energy from a battery powered car may be less than that from a fossil  
fuel powered car. For example, the cost of energy per mile of a nickel  
metal hydride battery powered car is 25% of that of a IC powered car  
["Advanced Automotive Technology: Visions of a Super-Efficient Family  
35 Car", National Technical Information Service, US Department of  
Commerce, US Office of Technology Assessment, Washington, DC PB96-

109202, September 1995]. But, current battery technology is trying to compete with something that it has little chance of imitating. Whichever battery technology proves to be superior, no known electric power plant will match the versatility and power of an internal combustion engine. A 5 typical IC engine yields more than 10,000 watt-hours of energy per kilogram of fuel, while the most promising battery technology yields 200 watt-hours per kilogram [New Scientist, April 15, (1995) pp. 32-35].

A high voltage battery would have the advantages of much greater power and much higher energy density. The limitations of battery 10 chemistry may be attributed to the binding energy of the anion of the oxidant. For example, the 2 volts provided by a lead acid cell is limited by the 1.46 eV electron affinity of the oxide anion of the oxidant  $PbO_2$ . An increase in the oxidation state of lead such as  $Pb^{2+} \rightarrow Pb^{3+} \rightarrow Pb^{4+}$  is possible in a plasma. Further oxidation of lead could also be achieved in 15 theory by electrochemical charging. But, higher lead oxidation states are not achievable because the oxide anion required to form a neutral compound would undergo oxidation by the highly oxidized lead cation. An anion with an extraordinary binding energy is required for a high voltage battery. One of the highest voltage batteries known is the lithium 20 fluoride battery with a voltage of about 6 volts. The voltage can be attributed to the higher binding energy of the fluoride ion. The electron affinity of halogens increases from the bottom of the Group VII elements to the top. Hydride ion may be considered a halide since it possess the same electronic structure. And, according to the binding energy trend, it 25 should have a high binding energy. However, the binding energy is only 0.75 eV which is much lower than the 3.4 eV binding energy of a fluoride ion.

An inorganic hydride compound having the formula  $KH_KHCO_3$  was isolated from an aqueous  $K_2CO_3$  electrolytic cell reactor. Inorganic 30 hydride clusters  $K[KH_KHCO_3]_n^*$  were identified by Time of Flight Secondary Ion Mass Spectroscopy (ToF-SIMS). A hydride ion with a binding energy of 22.8 eV has been observed by X-ray photoelectron spectroscopy (XPS) having upfield shifted solid state magic-angle spinning proton nuclear magnetic resonance ( $^1H$  MAS NMR) peaks. 35 Moreover, a polymeric structure is indicated by Fourier transform infrared (FTIR) spectroscopy. The discovery of a novel hydride ion with

a high binding energy has implications for a new field of hydride chemistry with applications such as a high voltage battery. Such extremely stable hydride ions may stabilize positively charged ions in an unprecedented highly charged state. A battery may be possible having  
5 projected specifications that surpass those of the internal combustion engine.

## EXPERIMENTAL

### 10 Synthesis

An electrolytic cell comprising a  $K_2CO_3$  electrolyte, a nickel wire cathode, and platinized titanium anodes was used to synthesize the  $KH KHCO_3$  sample [R. Mills, W. Good, and R. Shaubach, Fusion Technol. 25, 103 (1994)]. Briefly, the cell vessel comprised a 10 gallon (33 in. x 15 in.) Nalgene tank. An outer cathode comprised 5000 meters of 0.5 mm diameter clean, cold drawn nickel wire [NI 200 0.0197", HTN36NOAG1, A-1 Wire Tech, Inc., 840-39th Ave., Rockford, Illinois, 61109] wound on a polyethylene cylindrical support. A central cathode comprised 5000 meters of the nickel wire wound in a toroidal shape. The central cathode  
20 was inserted into a cylindrical, perforated polyethylene container that was placed inside the outer cathode with an anode array between the central and outer cathodes. The anode comprised an array of 15 platinized titanium anodes [Ten - Engelhard Pt/Ti mesh 1.6" x 8" with one 3/4" by 7" stem attached to the 1.6" side plated with 100 U series 3000; 25 and 5 - Engelhard 1" diameter x 8" length titanium tubes with one 3/4" x 7" stem affixed to the interior of one end and plated with 100 U Pt series 3000]. Before assembly, the anode array was cleaned in 3 M  $HCl$  for 5 minutes and rinsed with distilled water. The cathode was cleaned by placing it in a tank of 0.57 M  $K_2CO_3$ /3%  $H_2O_2$  for 6 hours and then rinsing  
30 it with distilled water. The anode was placed in the support between the central and outer cathodes, and the electrode assembly was placed in the tank containing electrolyte. The electrolyte solution comprised 28 liters of 0.57 M  $K_2CO_3$  (Alfa  $K_2CO_3$ , 99%). Electrolysis was performed at 20 amps constant current with a constant current ( $\pm 0.02\%$ ) power supply.  
35 Samples were isolated from the electrolytic cell by concentrating the  $K_2CO_3$  electrolyte about six fold using a rotary evaporator at 50 °C

until a yellow white polymeric suspension formed. Precipitated crystals of the suspension were then grown over three weeks by allowing the saturated solution to stand in a sealed round bottom flask at 25°C. Control samples utilized in the following experiments contained  $K_2CO_3$  (99%),  $KHCO_3$  (99.99%),  $HNO_3$  (99.99%), and  $KH$  (99%).

#### ToF-SIMS Characterization

The crystalline samples were sprinkled onto the surface of double-sided adhesive tapes and characterized using a Physical Electronics TFS-2000 ToF-SIMS instrument. The primary ion gun utilized a  $^{69}Ga^+$  liquid metal source. In order to remove surface contaminants and expose a fresh surface, the samples were sputter cleaned for 30 seconds using a  $40\mu m \times 40\mu m$  raster. The aperture setting was 3, and the ion current was 600 pA resulting in a total ion dose of  $10^{15} ions/cm^2$ .

During acquisition, the ion gun was operated using a bunched (pulse width 4 ns bunched to 1 ns) 15 kV beam [Microsc. Microanal. Microstruct., Vol. 3, 1, (1992); For recent specifications see PHI Trift II, ToF-SIMS Technical Brochure, Eden Prairie, MN 55344]. The total ion dose was  $10^{12} ions/cm^2$ . Charge neutralization was active, and the post accelerating voltage was 8000 V. Three different regions on each sample of  $(12\mu m)^2$ ,  $(18\mu m)^2$ , and  $(25\mu m)^2$  were analyzed. The positive and negative SIMS spectra were acquired. Representative post sputtering data is reported.

#### XPS Characterization

A series of XPS analyses were made on the crystalline samples using a Scienta 300 XPS Spectrometer. The fixed analyzer transmission mode and the sweep acquisition mode were used. The step energy in the survey scan was 0.5 eV, and the step energy in the high resolution scan was 0.15 eV. In the survey scan, the time per step was 0.4 seconds, and the number of sweeps was 4. In the high resolution scan, the time per step was 0.3 seconds, and the number of sweeps was 30. C 1s at 284.6 eV was used as the internal standard.

#### NMR Spectroscopy

<sup>1</sup>H MAS NMR was performed on the crystalline samples. The data were obtained on a custom built spectrometer operating with a Nicolet 1280 computer. Final pulse generation was from a tuned Henry radio amplifier. The <sup>1</sup>H NMR frequency was 270.6196 MHz. A 2  $\mu$ sec pulse corresponding to a 15° pulse length and a 3 second recycle delay were used. The window was  $\pm 31$  kHz. The spin speed was 4.5 kHz. The number of scans was 1000. Chemical shifts were referenced to external TMS. The offset was 1527.12 Hz, and the magnetic flux was 6.357 T.

10 FTIR Spectroscopy

Samples were transferred to an infrared transmitting substrate and analyzed by FTIR spectroscopy using a Nicolet Magna 550 FTIR Spectrometer with a NicPlan FTIR microscope. The number of scans was 500 for both the sample and background. The number of background scans was 500. The resolution was 8.000. A dry air purge was applied.

## RESULTS AND DISCUSSION

### ToF-SIMS

20 The positive ToF-SIMS spectrum obtained from the KHCO<sub>3</sub> control is shown in FIGURES 96 and 97. Moreover, the positive ToF-SIMS of a sample isolated from the electrolytic cell is shown in FIGURES 98 and 99. The respective hydride compounds and mass assignments appear in TABLE 3.11.1. In both the control and electrolytic samples, the positive ion spectrum are dominated by the K<sup>+</sup> ion. Two series of positive ions {K[K<sub>2</sub>CO<sub>3</sub>]<sub>n</sub><sup>+</sup> m/z = (39 + 138n) and K<sub>2</sub>OH[K<sub>2</sub>CO<sub>3</sub>]<sub>n</sub><sup>+</sup> m/z = (95 + 138n)} are observed in the KHCO<sub>3</sub> control. Other peaks containing potassium include KC<sup>+</sup>, K<sub>2</sub>O<sub>y</sub><sup>+</sup>, K<sub>2</sub>O<sub>y</sub>H<sub>z</sub><sup>+</sup>, KCO<sup>+</sup>, and K<sub>2</sub><sup>+</sup>. However, in the electrolytic cell sample, three new series of positive ions are observed at 25 {K[KH KHCO<sub>3</sub>]<sub>n</sub><sup>+</sup> m/z = (39 + 140n), K<sub>2</sub>OH[KH KHCO<sub>3</sub>]<sub>n</sub><sup>+</sup> m/z = (95 + 140n), and K<sub>2</sub>O[KH KHCO<sub>3</sub>]<sub>n</sub><sup>+</sup> m/z = (133 + 140n)}. These ions correspond to inorganic clusters containing novel hydride combinations (i.e. KH KHCO<sub>3</sub> units plus other positive fragments).

30

The comparison of the positive ToF-SIMS spectrum of the KHCO<sub>3</sub> control with the electrolytic cell sample shown in FIGURES 96-97 and 98-

99, respectively, demonstrates that the  $^{39}K^+$  peak of the electrolytic cell sample may saturate the detector and give rise to a peak that is atypical of the natural abundance of  $^{41}K$ . The natural abundance of  $^{41}K$  is 6.7%; whereas, the observed  $^{41}K$  abundance from the electrolytic cell sample is

5 57%. This atypical abundance was also confirmed using ESIToFMS [R. Mills, *The Grand Unified Theory of Classical Quantum Mechanics*, January 1999 Edition, BlackLight Power, Inc., Cranbury, New Jersey, Distributed by Amazon.com]. The high resolution mass assignment of the  $m/z = 41$  peak of the electrolytic sample was consistent with  $^{41}K$ , and no peak was  
10 observed at  $m/z = 42.98$  ruling out  $^{41}KH_2^+$ . Moreover, the natural abundance of  $^{41}K$  was observed in the positive ToF-SIMS spectra of  $KHCO_3$ ,  $KNO_3$ , and  $KI$  standards that were obtained with an ion current such that the  $^{39}K$  peak intensity was an order of magnitude higher than that given for the electrolytic cell sample. The saturation of the  $^{39}K$  peak  
15 of the positive ToF-SIMS spectrum by the electrolytic cell sample is indicative of a unique crystalline matrix [*Practical Surface Analysis*, 2nd Edition, Volume 2, Ion and Neutral Spectroscopy, D. Briggs, M. P. Seah (Editors), Wiley & Sons, New York, (1992)].

20 TABLE 3.11.1. The respective hydride compounds and mass assignments ( $m/z$ ) of the positive ToF-SIMS of an electrolytic cell sample.

Hydride Compound or Fragment	Nominal Mass $m/z$	Observed $m/z$	Calculated $m/z$	Difference Between Observed and Calculated $m/z$
$KH$	40	39.97	39.971535	0.0015
$K_2H$	79	78.940	78.935245	0.004
$(KH)_2$	80	79.942	79.94307	0.001
$KHKOH_2$	97	96.945	96.945805	0.0008
$KH_2(KH)_2$	121	120.925	120.92243	0.003
$KH KHCO_2$	124	123.925	123.93289	0.008
$KH_2KHO_4$	145	144.92	144.930535	0.010
$K(KOH)_2$	151	150.90	150.8966	0.003
$KH(KOH)_2$	152	151.90	151.904425	0.004

$KH_2(KOH)_2$	153	152.90	152.91225	0.012
$K[KH\ KHCO_3]$	179	178.89	178.8915	0.001
$KCO(KH)_3$	187	186.87	186.873225	0.003
$K_2OHKHCOH$	191	190.87	190.868135	0.002
$KH_2KOKHKOH$	193	192.89	192.883785	0.006
$K_3O(H_2O)_4$	205	204.92	204.92828	0.008
$K_2OH[KH\ KHCO_3]$	235	234.86	234.857955	0.002
$K[H_2CO_4\ KH\ KHCO_3]$	257	256.89	256.8868	0.003
$K_3O[KH\ KHCO_3]$	273	272.81	272.81384	0.004
$[KH_2CO_3]_3$	303	302.88	302.89227	0.012
$K[KH\ KHCO_3, K_2CO_3]$	317	316.80	316.80366	0.004
$K[KH\ KHCO_3]_2$	319	318.82	318.81931	0.001
$KH_2[KH\ KOH]_3$	329	328.80	328.7933	0.007
$KOH_2[KH\ KHCO_3]_2$	337	336.81	336.82987	0.020
$KH\ KO_2$ $[KH\ KHCO_3][KHCO_3]$	351	350.81	350.80913	0.001
$KKHK_2CO_3$ $[KH\ KHCO_3]$	357	356.77	356.775195	0.005
$KKH[KH\ KHCO_3]_2$	359	358.78	358.790845	0.011
$K_2OH[KH\ KHCO_3]_2$	375	374.78	374.785755	0.005
$K_2OH[KHKOH]_2$ $[KHCO_3]$	387	386.75	386.76238	0.012
$KKH_3KH_5[KH\ KHCO_3]_2$	405	404.79	404.80933	0.019
$K_3O[K_2CO_3]$ $[KH\ KHCO_3]$ or $K[KH\ KOH(K_2CO_3)_2]$	411	410.75	410.72599	0.024
$K_3O[KH\ KHCO_3]_2$	413	412.74	412.74164	0.002
$K[KH\ KOH]$ $[KH\ KHCO_3]_2$	415	414.74	414.75729	0.017
$KH_2OKHCO_3$ $[KH\ KHCO_3]_2$	437	436.81	436.786135	0.024
$KKHKCO_2[KH\ KHCO_3]_2$	442	441.74	441.744375	0.004

$K[KH KHCO_3]_1$	459	458.72	458.74711	0.027
$H[KH KOH]_2[K_2CO_3]_2$	469	468.70	468.708085	0.008
$K_2O_2H[KH KHCO_3]_2$				
$K[K_2CO_3][KHCO_3]_1$	477	476.72	476.744655	0.025
$K_2OH[KH KHCO_3]_3$	515	514.72	514.713555	0.006
$K_3O[KH KHCO_3]_3$	553	552.67	552.66944	0.001
$K[KH KHCO_3]_4$	599	598.65	598.67491	0.025
$K_2OH[KH KHCO_3]_4$	655	654.65	654.641355	0.009
$K_3O[KH KHCO_3]_4$	693	692.60	692.59724	0.003
$K[KH KHCO_3]_5$	739	738.65	738.60271	0.047
$K_3O[KH KHCO_3]_5$	833	832.50	832.52504	0.025
$K[KH KHCO_3]_6$	879	878.50	878.53051	0.031
$K_3O[KH KHCO_3]_6$	973	972.50	972.45284	0.047

The negative ion ToF-SIMS of the electrolytic cell sample was dominated by  $H^-$ ,  $O^-$ , and  $OH^-$  peaks. A series of nonhydride containing negative ions  $\{KCO_3[K_2CO_3]_n\text{ m/z} = (99 + 138n)\}$  was also present which implies that the hydride is lost with the proton during fragmentation of the compound  $KH KHCO_3$ .

### XPS

A survey spectrum was obtained over the region  $E_b = 0\text{ eV}$  to  $1200\text{ eV}$ . The primary element peaks allowed for the determination of all of the elements present in each sample isolated from the  $K_2CO_3$  electrolyte. The survey spectrum also detected shifts in the binding energies of the elements which had implications to the identity of the compound containing the elements. A high resolution XPS spectrum was also obtained of the low binding energy region ( $E_b = 0\text{ eV}$  to  $100\text{ eV}$ ) to determine the presence of novel XPS peaks.

No elements were present in the survey scans which can be assigned to peaks in the low binding energy region with the exception of a small variable contaminant of sodium at  $63\text{ eV}$  and  $31\text{ eV}$ , potassium at  $16.2\text{ eV}$  and  $32.1\text{ eV}$ , and oxygen at  $23\text{ eV}$ . Accordingly, any other peaks

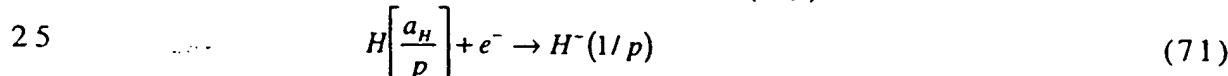
in this region must be due to novel species. The  $K\ 3s$  and  $K\ 3p$  are shown in Figure 100 at 16.2 eV and 32.1 eV, respectively. A weak  $Na\ 2s$  is observed at 63 eV. The  $O\ 2s$ , which is weak compared to the potassium peaks of  $K_2CO_3$ , is typically present at 23 eV, but is broad or obscured in

5 FIGURE 100. Peaks centered at 22.8 eV and 38.8 eV which do not correspond to any other primary element peaks were observed. The intensity and shift match shifted  $K\ 3s$  and  $K\ 3p$ . Hydrogen is the only element which does not have primary element peaks; thus, it is the only candidate to produce the shifted peaks. These peaks may be shifted by a  
10 highly binding hydride ion with a binding energy of 22.8 eV that bonds to potassium  $K\ 3p$  and shifts the peak to this energy. In this case, the  $K\ 3s$  is similarly shifted. These peaks were not present in the case of the XPS of matching samples isolated from an identical electrolytic cell except that  $Na_2CO_3$  replaced  $K_2CO_3$ , as the electrolyte.

15 A novel hydride ion having extraordinary chemical properties given by Mills [R. Mills, *The Grand Unified Theory of Classical Quantum Mechanics*, January 1999 Edition, BlackLight Power, Inc., Cranbury, New Jersey, Distributed by Amazon.com] is predicted to form by the reaction of an electron with a hydrino (Eq. (71)), a hydrogen atom having a  
20 binding energy given by

$$\text{Binding Energy} = \frac{13.6 \text{ eV}}{\left(\frac{1}{p}\right)^2} \quad (70)$$

where  $p$  is an integer greater than 1, designated as  $H\left[\frac{a_H}{p}\right]$  where  $a_H$  is the radius of the hydrogen atom. The resulting hydride ion is referred to as a hydrino hydride ion, designated as  $H^-(1/p)$ .



The hydrino hydride ion is distinguished from an ordinary hydride ion having a binding energy of 0.8 eV. The latter is hereafter referred to as "ordinary hydride ion". The hydrino hydride ion is predicted [R. Mills, *The Grand Unified Theory of Classical Quantum Mechanics*, January 1999 Edition, BlackLight Power, Inc., Cranbury, New Jersey, Distributed by Amazon.com] to comprise a hydrogen nucleus and two indistinguishable electrons at a binding energy according to the following formula:

$$\text{Binding Energy} = \frac{\hbar^2 \sqrt{s(s+1)}}{8\mu_e a_0^2 \left[ \frac{1 + \sqrt{s(s+1)}}{p} \right]^2} - \frac{\pi \mu_0 e^2 \hbar^2}{m_e^2 a_0^3} \left( 1 + \frac{2^2}{\left[ \frac{1 + \sqrt{s(s+1)}}{p} \right]^3} \right) \quad (72)$$

where  $p$  is an integer greater than one,  $s = 1/2$ ,  $\pi$  is pi,  $\hbar$  is Planck's constant bar,  $\mu_0$  is the permeability of vacuum,  $m_e$  is the mass of the electron,  $\mu_e$  is the reduced electron mass,  $a_0$  is the Bohr radius, and  $e$  is the elementary charge. The ionic radius is

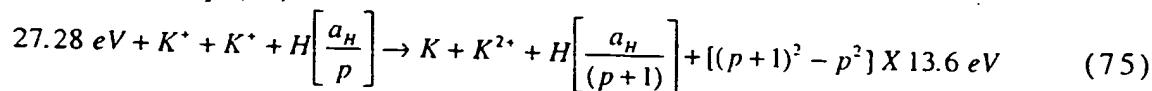
$$r_i = \frac{a_0}{p} \left( 1 + \sqrt{s(s+1)} \right); s = \frac{1}{2} \quad (73)$$

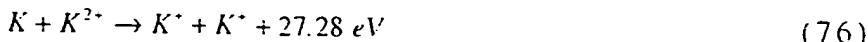
From Eq. (73), the radius of the hydrino hydride ion  $H^- (1/p)$ ;  $p = \text{integer}$  is  $\frac{1}{p}$  that of ordinary hydride ion,  $H^- (1/1)$ . The XPS peaks centered at 22.8 eV and 38.8 eV are assigned to shifted  $K\ 3s$  and  $K\ 3p$ . The anion does not correspond to any other primary element peaks; thus, it may correspond to the  $H^- (n=1/6) E_b = 22.8\text{ eV}$  hydride ion predicted by Mills [R. Mills, *The Grand Unified Theory of Classical Quantum Mechanics*, January 1999 Edition, BlackLight Power, Inc., Cranbury, New Jersey, Distributed by Amazon.com] where  $E_b$  is the predicted binding energy.

Hydrinos are predicted to form by reacting an ordinary hydrogen atom with a catalyst having a net enthalpy of reaction of about

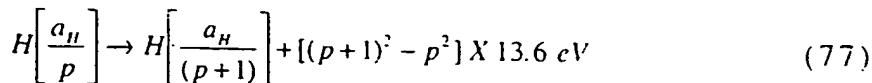
$$m \cdot 27.21\text{ eV} \quad (74)$$

where  $m$  is an integer [R. Mills, *The Grand Unified Theory of Classical Quantum Mechanics*, January 1999 Edition, BlackLight Power, Inc., Cranbury, New Jersey, Distributed by Amazon.com]. This catalysis releases energy from the hydrogen atom with a commensurate decrease in size of the hydrogen atom,  $r_n = n a_H$ . For example, the catalysis of  $H(n=1)$  to  $H(n=1/2)$  releases 40.8 eV, and the hydrogen radius decreases from  $a_H$  to  $\frac{1}{2} a_H$ . One such catalytic system involves potassium. The second ionization energy of potassium is 31.63 eV; and  $K^+$  releases 4.34 eV when it is reduced to  $K$ . The combination of reactions  $K^+$  to  $K^{2+}$  and  $K^+$  to  $K$ , then, has a net enthalpy of reaction of 27.28 eV, which is equivalent to  $m=1$  in Eq. (74).





The overall reaction is



The energy given off during catalysis is much greater than the energy lost to the catalyst. The energy released is large as compared to conventional chemical reactions. For example, when hydrogen and oxygen gases undergo combustion to form water



the known formation enthalpy of water is  $\Delta H_f = -286 \text{ kJ/mole}$  or 1.48 eV

per hydrogen atom. By contrast, each ordinary hydrogen atom ( $n=1$ ) catalysis releases a net of 40.8 eV. The exothermic reactions Eq. (75-77), Eq. (71) and the enthalpy of formation of  $KHKHCO_3$ , could explain the observation of excess enthalpy of  $1.6 \times 10^9 \text{ J}$  that exceeded the total input enthalpy given by the product of the electrolysis voltage and current over time by a factor greater than 8 [R. Mills, W. Good, and R. Shaubach, Fusion Technol. 25, 103 (1994)].

XPS further confirmed the ToF-SIMS data by showing shifts of the primary elements. The splitting of the principle peaks of the survey XPS spectrum is indicative of multiple forms of bonding involving the atom of each split peak. For example, the XPS survey spectrum shown in FIGURE 101 shows extraordinary potassium and oxygen peak shifts. All of the potassium primary peaks are shifted to about the same extent as that of the  $K 3s$  and  $K 3p$ . In addition, extraordinary  $O 1s$  peaks of the electrolytic cell sample were observed at 537.5 eV and 547.8 eV; whereas, a single  $O 1s$  was observed in the XPS spectrum of  $K_2CO_3$  at 532.0 eV. The results are not due to uniform charging as the internal standard  $C 1s$  remains the same at 284.6 eV. The results are not due to differential charging because the peak shapes of carbon and oxygen are normal, and no tailing of these peaks was observed. The binding energies of the  $K_2CO_3$  control and an electrolytic cell sample are shown in TABLE 3.11.2. The range of binding energies from the literature [C. D. Wagner, W. M. Riggs, L. E. Davis, J. F. Moulder, G. E. Mulikenberg (Editor), *Handbook of X-ray Photoelectron Spectroscopy*, Perkin-Elmer Corp., Eden Prairie, Minnesota, (1997)] for the peaks of interest are given in the final row of

TABLE 3.11.2. The  $K\ 3p$ ,  $K\ 3s$ ,  $K\ 2p_{3/2}$ ,  $K\ 2p_{1/2}$ , and  $K\ 2s$  XPS peaks and the  $O\ 1s$  XPS peaks shifted to an extent greater than those of known compounds may correspond to and identify  $KH\ KHCO_3$ .

5 TABLE 3.11.2. The binding energies of XPS peaks of  $K_2CO_3$  and an electrolytic cell sample.

XPS #	$C\ 1s$ (eV)	$O\ 1s$ (eV)	$K\ 3p$ (eV)	$K\ 3s$ (eV)	$K\ 2p_3$ (eV)	$K\ 2p_1$ (eV)	$K\ 2s$ (eV)
$K_2CO_3$	288.4	532.0	18	34	292.4	295.2	376.7
Electrolytic Cell Sample	288.5	530.4	16.2	32.1	291.5	293.7	376.6
		537.5	22.8	38.8	298.5	300.4	382.6
		547.8					
Min	280.5	529			292		
Max	293	535			293.2		

### NMR

10 The signal intensities of the  $^1H$  MAS NMR spectrum of the  $K_2CO_3$  reference were relatively low. It contained a water peak at 1.208 ppm, a peak at 5.604 ppm, and very broad weak peaks at 13.2 ppm, and 16.3 ppm. The  $^1H$  MAS NMR spectrum of the  $KHCO_3$  reference contained a large peak at 4.745 with a small shoulder at 5.150 ppm, a broad peak at 13.203 ppm, and small peak at 1.2 ppm.

15 The  $^1H$  MAS NMR spectra of an electrolytic cell sample is shown in FIGURE 102. The peak assignments are given in TABLE 3.11.3. The reproducible peaks assigned to  $KH\ KHCO_3$  in TABLE 3.11.3 were not present in the controls except for the peak assigned to water at +5.066 ppm. The novel peaks could not be assigned to hydrocarbons.

20 Hydrocarbons were not present in the electrolytic cell sample based on the TOFSIMS spectrum and FTIR spectra which were also obtained (see below). The novel peaks without identifying assignment are consistent with  $KH\ KHCO_3$ . The NMR peaks of the hydride ion of potassium hydride were observed at 1.192 ppm and 0.782 ppm relative to TMS. The upfield peaks of FIGURE 102 are assigned to novel hydride ion ( $KH^-$ ) in different environments. The down field peaks are assigned to the proton of the

potassium hydrogen carbonate species in different chemical environments ( $-KHCO_3$ ).

5 TABLE 3.11.3. The NMR peaks of an electrolytic cell sample with their assignments.

Peak at Shift (ppm)	Assignment
+34.54	side band of +17.163 peak
+22.27	side band of +5.066 peak
+17.163	$KH\ KHCO_3$
+10.91	$KH\ KHCO_3$
+8.456	$KH\ KHCO_3$
+7.50	$KH\ KHCO_3$
+5.066	$H_2O$
+1.830	$KH\ KHCO_3$
-0.59	side band of +17.163 peak
-12.05	$KH\ KHCO_3$ a
-15.45	$KH\ KHCO_3$

a small shoulder is observed on the -12.05 peak  
which is the side band of the +5.066 peak

### FTIR

- 10 The FTIR spectra of  $K_2CO_3$  (99%) and  $KHCO_3$  (99.99%) were compared with that of an electrolytic cell sample. A spectrum of a mixture of the bicarbonate and the carbonate was produced by digitally adding the two reference spectra. The two standards alone and the mixed standards were compared with that of the electrolytic cell sample.
- 15 From the comparison, it was determined that the electrolytic cell sample contained potassium carbonate but did not contain potassium bicarbonate. The unknown component could be a bicarbonate other than potassium bicarbonate. The spectrum of potassium carbonate was digitally subtracted from the spectrum of the electrolytic cell sample.

Several bands were observed including bands in the  $1400 - 1600\text{ cm}^{-1}$  region. Some organic nitrogen compounds (e.g. acrylamides, pyrrolidinones) have strong bands in the region  $1660\text{ cm}^{-1}$  [D. Lin-Vien, N. B. Colthup, W. G. Fateley, J. G. Grassellic, *The Handbook of Infrared and Raman Characteristic Frequencies of Organic Molecules*, Academic Press, Inc., (1991)]. However, the lack of any detectable C-H bands ( $\approx 2800 - 3000\text{ cm}^{-1}$ ) and the bands present in the  $700$  to  $1100\text{ cm}^{-1}$  region indicate an inorganic material [R. A. Nyquist and R. O. Kagel, (Editors), *Infrared Spectra of Inorganic Compounds*, Academic Press, New York, (1971)]. Peaks that are not assignable to potassium carbonate were observed at  $3294$ ,  $3077$ ,  $2883$ ,  $1100\text{ cm}^{-1}$ ,  $2450$ ,  $1660$ ,  $1500$ ,  $1456$ ,  $1423$ ,  $1300$ ,  $1154$ ,  $1023$ ,  $846$ ,  $761$ , and  $669\text{ cm}^{-1}$ .

The overlap FTIR spectrum of the electrolytic cell sample and the FTIR spectrum of the reference potassium carbonate appears in FIGURE 103. In the  $700$  to  $2500\text{ cm}^{-1}$  region, the peaks of the electrolytic cell sample closely resemble those of potassium carbonate, but they are shifted about  $50\text{ cm}^{-1}$  to lower frequencies. The shifts are similar to those observed by replacing potassium ( $K_2CO_3$ ) with rubidium ( $Rb_2CO_3$ ) as demonstrated by comparing their IR spectra [M. H. Brooker, J. B. Bates, *Spectrochimica Acta*, Vol. 30A, (1994), pp. 2211-2220]. The shifted peaks may be explained by a polymeric structure for the compound  $KH\text{KHCO}_3$  identified by ToF-SIMS, XPS, and NMR.

#### Further Analytical Tests

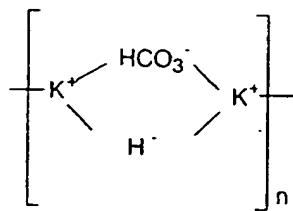
X-ray diffraction (XRD), elemental analysis using inductively coupled plasma (ICP), and Raman spectroscopy were also performed on the electrolytic sample [R. Mills, *The Grand Unified Theory of Classical Quantum Mechanics*, January 1999 Edition, BlackLight Power, Inc., Cranbury, New Jersey, Distributed by Amazon.com]. The XRD data indicated that the diffraction pattern of the electrolytic cell sample does not match that of either  $KH$ ,  $KHCO_3$ ,  $K_2CO_3$ , or  $KOH$ . The elemental analysis supports  $KH\text{KHCO}_3$ . In addition to the known Raman peaks of  $KHCO_3$  and a small peak assignable to  $K_2CO_3$ , unidentified peaks at  $1685\text{ cm}^{-1}$  and  $835\text{ cm}^{-1}$  were present. Work in progress [R. Mills, *The Grand Unified Theory of Classical Quantum Mechanics*, January 1999 Edition, BlackLight Power, Inc., Cranbury, New Jersey, Distributed by

Amazon.com] demonstrates that  $KH\text{KHCO}_3$  may also be formed by a reaction of gaseous  $KI$  with atomic hydrogen in the presence of  $K_2\text{CO}_3$ . In addition to the previous analytical studies, the fragment  $KK_2\text{CO}_3$  corresponding to  $KH\text{KHCO}_3$ , was observed by electrospray ionization time 5 of flight mass spectroscopy as a chromatographic peak on a C18 liquid chromatography column typically used to separate organic compounds. No chromatographic peaks were observed in the case of inorganic compound controls  $KI$ ,  $KHCO_3$ ,  $K_2\text{CO}_3$ , and  $KOH$ .

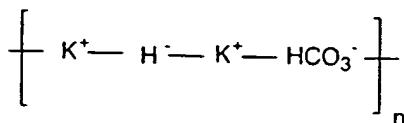
## 10 DISCUSSION

Alkali and alkaline earth hydrides react violently with water to release hydrogen gas which subsequently ignites due to the exothermic reaction with water. Typically metal hydrides decompose upon heating 15 at a temperature well below the melting point of the parent metal. These saline hydrides, so called because of their saltlike or ionic character, are the monohydrides of the alkali metals and the dihydrides of the alkaline-earth metals, with the exception of beryllium.  $BeH_2$  appears to be a hydride with bridge type bonding rather than an ionic hydride. Highly 20 polymerized molecules held together by hydrogen-bridge bonding is exhibited by boron hydrides and aluminum hydride. Based on the known structures of these hydrides, the ToF-SIMS hydride clusters such as  $K[\text{KH}\text{KHCO}_3]_n^+$ , the XPS peaks observed at 22.8 eV and 33.8 eV, upfield NMR peaks assigned to hydride ion, and the shifted FTIR peaks, the 25 present novel hydride compound may be a polymer,  $[\text{KH}\text{KHCO}_3]_n$ , with a structural formula which is similar to boron and aluminum hydrides. The reported novel compound appeared polymeric in the concentrated electrolytic solution and in distilled water.  $[\text{KH}\text{KHCO}_3]_n$  is extraordinarily stable in water; whereas, potassium hydride reacts violently with water.

30 As an example of the structures of this compound, the  $K[\text{KH}\text{KHCO}_3]_n^+ m/z = (39 + 140n)$  series of fragment peaks is tentatively assigned to novel hydride bridged or linear potassium bicarbonate compounds having a general formula such as  $[\text{KHKHCO}_3]_n$ ,  $n = 1, 2, 3, \dots$ . General structural formulas may be



and



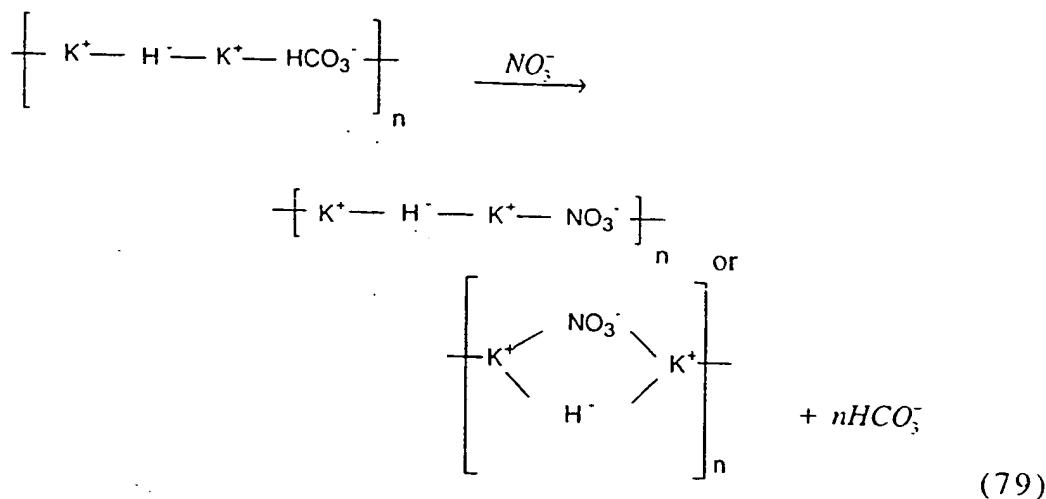
Liquid chromatography/ESIToFMS studies are in progress to support the polymer assignment.

The observation of inorganic hydride fragments such as  $\text{K}[\text{KH KHCO}_3]^+$  in the positive ToF-SIMS spectra of samples isolated from the electrolyte following acidification indicates the stability of the novel potassium hydride potassium bicarbonate compound [R. Mills, *The Grand Unified Theory of Classical Quantum Mechanics*, January 1999 Edition, BlackLight Power, Inc., Cranbury, New Jersey, Distributed by Amazon.com]. The electrolyte was acidified with  $\text{HNO}_3$  to  $\text{pH} = 2$  and boiled to dryness to prepare samples to determine whether  $\text{KH KHCO}_3$

was reactive under these conditions. Ordinarily no  $\text{K}_2\text{CO}_3$  would be present, and the sample would be converted to  $\text{KNO}_3$ . Crystals were isolated by dissolving the dried crystals in water, concentrating the solution, and allowing crystals to precipitate. ToF-SIMS was performed on these crystals. The positive spectrum contained elements of the series of inorganic hydride clusters  $\{\text{K}[\text{KH KHCO}_3]^+_n \text{ m/z } (39 + 140n),$

$\text{K}_2\text{OH}[\text{KH KHCO}_3]^+_n \text{ m/z } (95 + 140n)$ , and  $\text{K}_3\text{O}[\text{KH KHCO}_3]^+_n \text{ m/z } (133 + 140n)\}$  that were observed in the positive ToF-SIMS spectrum of the electrolytic cell sample as discussed in the ToF-SIMS Results Section and given in FIGURES 98-99 and TABLE 3.11.1. The presence of bicarbonate carbon ( $\text{C } 1s \equiv 289.5 \text{ eV}$ ) was observed in the XPS of the sample from the  $\text{HNO}_3$

acidified electrolyte. In addition, fragments of compounds formed by the displacement of hydrogen carbonate by nitrate were observed [R. Mills, *The Grand Unified Theory of Classical Quantum Mechanics*, January 1999 Edition, BlackLight Power, Inc., Cranbury, New Jersey, Distributed by Amazon.com]. A general structural formula for the reaction maybe



During acidification of the  $\text{K}_2\text{CO}_3$  electrolyte the pH repetitively increased from 3 to 9 at which time additional acid was added with carbon dioxide release. The increase in pH (release of base by the titration reactant) was dependent on the temperature and concentration of the solution. A reaction consistent with this observation is the displacement reaction of  $\text{NO}_3^-$  for  $\text{HCO}_3^{2-}$  as given by Eq. (79).

10

## CONCLUSION

The ToF-SIMS, XPS, and NMR results confirm the identification of  $\text{KH}_2\text{KHCO}_3$  with a new state of hydride ion. The chemical structure and properties of this compound having a hydride ion with a high binding energy are indicative of a new field of hydride chemistry. The novel hydride ion may combine with other cations such as other alkali cations and alkaline earth, rare earth, and transition element cations. Thousands of novel compounds may be synthesized with extraordinary properties relative to the corresponding compounds having ordinary hydride ions. These novel compounds may have a breath of applications. For example, a high voltage battery according to the hydride binding energy of 22.8 eV observed by XPS may be possible having projected specifications that surpass those of the internal combustion engine.

25

### 3.3 Synthesis and Characterization of Potassium Iodo Hydride

#### ABSTRACT

5 A novel inorganic hydride compound *KHI* which comprises a high binding energy hydride ions was synthesized by reaction of atomic hydrogen with potassium metal and potassium iodide. Potassium iodo hydride was identified by time of flight secondary ion mass spectroscopy, X-ray photoelectron spectroscopy, proton and  $^{39}K$  nuclear magnetic resonance 10 spectroscopy, Fourier transform infrared (FTIR) spectroscopy, electrospray ionization time of flight mass spectroscopy, liquid chromatography/mass spectroscopy, thermal decomposition with analysis by gas chromatography, and mass spectroscopy, and elemental analysis. 15 Hydride ions with increased binding energies may form many novel compounds with broad applications.

#### INTRODUCTION

Intense EUV emission was observed at low temperatures (e.g.  $< 10^3 K$ ) from atomic hydrogen and certain atomized elements with one or 20 more unpaired electrons or certain gaseous ions which ionize at integer multiples of the potential energy of atomic hydrogen [R. Mills, J. Dong, Y. Lu, "Observation of Extreme Ultraviolet Hydrogen Emission from Incandescently Heated Hydrogen Gas with Certain Catalysts", Science, (1999) in progress]. Based on its exceptional emission, we used 25 potassium metal as a catalyst to release energy from atomic hydrogen. Mills predicts an exothermic reaction whereby certain atoms or ions serve as catalysts [R. Mills, *The Grand Unified Theory of Classical Quantum Mechanics*, January 1999 Edition, BlackLight Power, Inc., Cranbury, New Jersey, Distributed by Amazon.com] to release energy 30 from hydrogen to produce an increased binding energy hydrogen atom called a hydrino having a binding energy of

$$\text{Binding Energy} = \frac{13.6 \text{ eV}}{\left(\frac{1}{p}\right)^2} \quad (80)$$

where  $p$  is an integer greater than 1, designated as  $H\left[\frac{a_H}{p}\right]$  where  $a_H$  is the radius of the hydrogen atom. Hydrinos are predicted to form by reacting an ordinary hydrogen atom with a catalyst having a net enthalpy of reaction of about

5

$$m \cdot 27.2 \text{ eV} \quad (81)$$

where  $m$  is an integer [R. Mills, *The Grand Unified Theory of Classical Quantum Mechanics*, January 1999 Edition, BlackLight Power, Inc., Cranbury, New Jersey, Distributed by Amazon.com]. This catalysis releases energy from the hydrogen atom with a commensurate decrease 10 in size of the hydrogen atom,  $r_n = na_H$ . For example, the catalysis of  $H(n=1)$  to  $H(n=1/2)$  releases  $40.8 \text{ eV}$ , and the hydrogen radius decreases from  $a_H$  to  $\frac{1}{2}a_H$ .

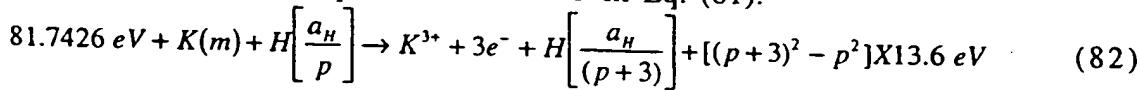
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A catalytic system is provided by the ionization of  $t$  electrons from an atom each to a continuum energy level such that the sum of the ionization energies of the  $t$  electrons is approximately  $m \times 27.2 \text{ eV}$  where  $m$  is an integer. One such catalytic system involves potassium. The first, second, and third ionization energies of potassium are  $4.34066 \text{ eV}$ ,  $31.63 \text{ eV}$ ,  $45.806 \text{ eV}$ , respectively [D. R. Linde, CRC Handbook of Chemistry and Physics, 78 th Edition, CRC Press, Boca Raton, Florida, (1997), p. 10-214 to 10-216.

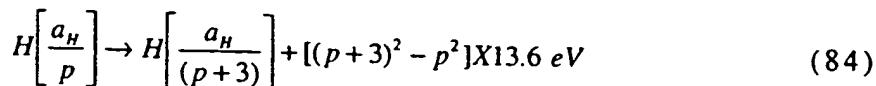
4. Microsc. Microanal. Microstruct., Vol. 3, 1, (1992)]. The triple ionization ( $t=3$ ) reaction of  $K$  to  $K^{3+}$ , then, has a net enthalpy of reaction of  $81.7426 \text{ eV}$ , which is equivalent to  $m=3$  in Eq. (81).



25

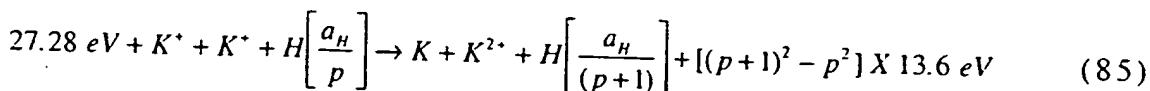


And, the overall reaction is

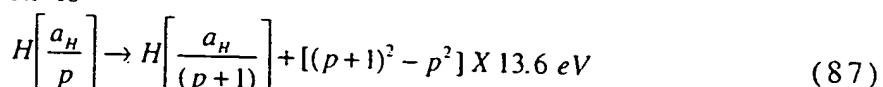


Potassium ions can also provide a net enthalpy of a multiple of that of the potential energy of the hydrogen atom. The second ionization 30 energy of potassium is  $31.63 \text{ eV}$ ; and  $K^+$  releases  $4.34 \text{ eV}$  when it is reduced to  $K$ . The combination of reactions  $K^+$  to  $K^{2+}$  and  $K^+$  to  $K$ , then,

has a net enthalpy of reaction of 27.28 eV, which is equivalent to  $m=1$  in Eq. (81).



5 The overall reaction is



A novel hydride ion having extraordinary chemical properties given by Mills [R. Mills, *The Grand Unified Theory of Classical Quantum Mechanics*, January 1999 Edition, BlackLight Power, Inc., Cranbury, New Jersey, Distributed by Amazon.com] is predicted to form by the reaction of an electron with a hydrino (Eq. (88)). The resulting hydride ion is referred to as a hydrino hydride ion, designated as  $H^-(1/p)$ .



15 The hydrino hydride ion is distinguished from an ordinary hydride ion having a binding energy of 0.8 eV. The latter is hereafter referred to as "ordinary hydride ion". The hydrino hydride ion is predicted [R. Mills, *The Grand Unified Theory of Classical Quantum Mechanics*, January 1999 Edition, BlackLight Power, Inc., Cranbury, New Jersey, Distributed by Amazon.com] to comprise a hydrogen nucleus and two indistinguishable electrons at a binding energy according to the following formula:

$$\text{Binding Energy} = \frac{\hbar^2 \sqrt{s(s+1)}}{8\mu_e a_0^2 \left[ \frac{1 + \sqrt{s(s+1)}}{p} \right]^2} - \frac{\pi \mu_0 e^2 \hbar^2}{m_e^2 a_0^3} \left( 1 + \frac{2^2}{\left[ \frac{1 + \sqrt{s(s+1)}}{p} \right]^3} \right) \quad (89)$$

where  $p$  is an integer greater than one,  $s=1/2$ ,  $\pi$  is pi,  $\hbar$  is Planck's constant bar,  $\mu_0$  is the permeability of vacuum,  $m_e$  is the mass of the electron,  $\mu_e$  is the reduced electron mass,  $a_0$  is the Bohr radius, and  $e$  is the elementary charge. The ionic radius is

$$r_i = \frac{a_0}{p} \left( 1 + \sqrt{s(s+1)} \right); s = \frac{1}{2} \quad (90)$$

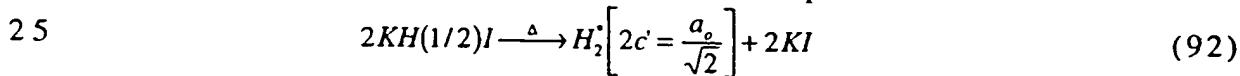
From Eq. (90), the radius of the hydrino hydride ion  $H^-(1/p)$ ;  $p=\text{integer}$  is  $\frac{1}{p}$  that of ordinary hydride ion,  $H^-(1/1)$ .

A novel inorganic hydride compound  $KHI$  which comprises high binding energy hydride ions was synthesized by reaction of atomic hydrogen with potassium metal and potassium iodide. Potassium iodo hydride was identified by time of flight secondary ion mass spectroscopy (ToF-SIMS), X-ray photoelectron spectroscopy (XPS), proton and  $^{39}K$  nuclear magnetic resonance spectroscopy (NMR), Fourier transform infrared (FTIR) spectroscopy, electrospray ionization time of flight mass spectroscopy (ESITOFMS), liquid chromatography/mass spectroscopy (LC/MS), thermal decomposition with analysis by gas chromatography (GC), and mass spectroscopy (MS), and elemental analysis.

Alkali and alkaline earth hydrides react violently with water to release hydrogen gas which subsequently ignites due to the exothermic reaction with water. Typically metal hydrides decompose upon heating at a temperature well below the melting point of the parent metal. These saline hydrides, so called because of their saltlike or ionic character, are the monohydrides of the alkali metals and the dihydrides of the alkaline-earth metals. Mills predicts a hydrogen-type molecule having a first binding energy of about

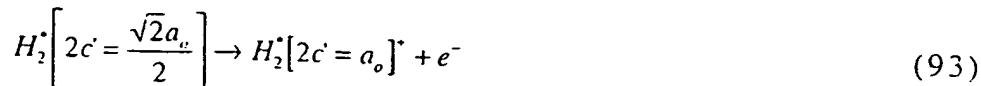
$$\text{Binding Energy} = \frac{15.5}{\left(\frac{1}{p}\right)^2} \text{ eV} \quad (91)$$

Dihydrino molecules may be produced by the thermal decomposition of hydrino hydride ions.  $H^-(1/2)$  may be less reactive and more thermally stable than ordinary potassium hydride, but may react to form a hydrogen-type molecule. Potassium iodo hydride  $KH(1/2)I$  may be heated to release dihydrino by thermal decomposition.



where  $2c'$  is the internuclear distance and  $a_0$  is the Bohr radius [R. Mills, *The Grand Unified Theory of Classical Quantum Mechanics*, January 1999 Edition, BlackLight Power, Inc., Cranbury, New Jersey, Distributed by Amazon.com]. The possibility of releasing dihydrino by thermally decomposing potassium iodo hydride with identification by gas chromatography was explored.

The first ionization energy,  $IP_1$ , of the dihydrino molecule



is  $IP_1 = 62$  eV ( $p = 2$  in Eq. (91)); whereas, the first ionization energy of ordinary molecular hydrogen,  $H_2[2c' = \sqrt{2}a_o]$ , is 15.46 eV. Thus, the possibility of using mass spectroscopy to discriminate  $H_2[2c' = \sqrt{2}a_o]$  from 5  $H_2^{\cdot} \left[ 2c' = \frac{a_o}{\sqrt{2}} \right]$  on the basis of the large difference between the ionization energies of the two species was explored. A novel high binding energy hydrogen molecule assigned to dihydrino  $H_2^{\cdot} \left[ 2c' = \frac{a_o}{\sqrt{2}} \right]$  was identified by the thermal decomposition of KHI with analysis by gas chromatography, and mass spectroscopy.

10 The discovery of novel hydride ions with high binding energies has implications for a new field of hydride chemistry. These novel compositions of matter and associated technologies may have far-reaching applications in many industries including chemical, electronics, computer, military, energy, and aerospace in the form of products such as 15 batteries, propellants, solid fuels, munitions, surface coatings, structural materials, and chemical processes.

## EXPERIMENTAL

### Synthesis

Potassium iodo hydride was prepared in a stainless steel gas cell shown in FIGURE 104 comprising a Ti screen hydrogen dissociator (Belleville Wire Cloth Co., Inc.), potassium metal catalyst (Aldrich Chemical Company), and KI (Aldrich Chemical Company 99.9 %) as the reactant. The 304-stainless steel cell 301 was in the form of a tube having an internal cavity 317 of 359 millimeters in length and 73 millimeters in diameter. The top end of the cell was welded to a high vacuum 4 5/8 inch bored through conflat flange 318. The mating blank conflat flange 319 contained a single coaxial hole in which was welded a 3/8 inch diameter stainless steel tube 302 that was 100 cm in length and contained an inner coaxial tube of 1/8 inch diameter. A silver plated copper gasket was placed between the two flanges. The two flanges are held together with 10 circumferential bolts. The bottom of the 3/8 inch

tube 302 was flush with the bottom surface of the top flange 319. The outer tube 302 served as a vacuum line from the cell and the inner tube served as a hydrogen or helium supply line to the cell. The cell 301 was surrounded by four heaters 303, 304, 305, and 306. Concentric to the  
5 heaters was high temperature insulation (AL 30 Zircar) 307. Each of the four heaters were individually thermostatically controlled.

The cylindrical wall of the cell 301 was lined with two layers of Ti screen 308 totaling 150 grams. 75 grams of crystalline KI 309 was poured into the cell 301. About 0.5 grams of potassium metal was added  
10 to the cell under an argon atmosphere. The cell 301 was then continuously evacuated with a high vacuum turbo pump 310 to reach 50 millitorr measured by a pressure gauge (Varian Convector, Pirrani type)  
15 312. The cell was heated by supplying power to the heaters 303, 304, 305, and 306. The heater power of the largest heater 305 was measured using a wattmeter (Clarke -Hess model 259). The temperature of the cell was measured with a type K thermocouple (Omega). The cell temperature was then slowly increased over 2 hours to 300 °C using the heaters that were controlled by a type 97000 controller. The power to  
20 the largest heater 305 and the cell temperature and pressure were continuously recorded by a DAS. The vacuum pump valve 311 was closed. Hydrogen was supplied from tank 316 through regulator 315 to the valve 314. Hydrogen was slowly added to maintain a pressure within the range of 1000 torr to 1500 torr by opening valve 313. The temperature of the cell was then slowly increased to 650 °C over 5 hours.  
25 The hydrogen valve 313 was closed except to maintain the pressure at 1500 torr. After 24 hours, the temperature of the cell 301 was reduced to 400 °C at a rate of 15 °C/hr. The hydrogen tank 316 was replaced by a helium tank. Helium which was flowed through the inner supply line 302 to the cell while a vacuum was pulled on the outer vacuum line 302 to remove volatilized potassium metal at 400 °C. The cell was then cooled and opened. About 75 grams of blue crystals were observed to have  
30 formed in the bottom of the cell.

#### ToF-SIMS Characterization

35 The crystalline samples were sprinkled onto the surface of a double-sided adhesive tape and characterized using a Physical Electronics

TFS-2000 ToF-SIMS instrument. The primary ion gun utilized a  $^{69}\text{Ga}^+$  liquid metal source. In order to remove surface contaminants and expose a fresh surface, the samples were sputter cleaned for 30 seconds using a  $40\mu\text{m} \times 40\mu\text{m}$  raster. The aperture setting was 3, and the ion current  
5 was 600 pA resulting in a total ion dose of  $10^{15} \text{ ions/cm}^2$ .

During acquisition, the ion gun was operated using a bunched (pulse width 4 ns bunched to 1 ns) 15 kV beam [Microsc. Microanal. Microstruct., Vol. 3, 1, (1992); For recent specifications see PHI Trift II, ToF-SIMS Technical Brochure, Eden Prairie, MN 55344]. The total ion  
10 dose was  $10^{12} \text{ ions/cm}^2$ . Charge neutralization was active, and the post accelerating voltage was 8000 V. Three different regions on each sample of  $(12\mu\text{m})^2$ ,  $(18\mu\text{m})^2$ , and  $(25\mu\text{m})^2$  were analyzed. The positive and negative SIMS spectra were acquired. Representative post sputtering data is reported.

15

#### XPS Characterization

A series of XPS analyses were made on the crystalline samples using a Scienta 300 XPS Spectrometer. The fixed analyzer transmission mode and the sweep acquisition mode were used. The step energy in the survey scan was 0.5 eV, and the step energy in the high resolution scan was 0.15 eV. In the survey scan, the time per step was 0.4 seconds, and the number of sweeps was 4. In the high resolution scan, the time per step was 0.3 seconds, and the number of sweeps was 30.. C 1s at 284.5 eV was used as the internal standard.

25

#### NMR Spectroscopy

$^1\text{H}$  MAS NMR was performed on the blue crystals. The data were recorded on a Bruker DSX-400 spectrometer at 400.13 MHz. Samples were packed in zirconia rotors and sealed with airtight O-ring caps under an inert atmosphere. The MAS frequency was 4.5 kHz. During data acquisition, the sweep width was 60.06 kHz; the dwell time was 8.325  $\mu\text{sec}$ , and the acquisition time was 0.03415 sec/scan. The number of scans was typically 32 or 64. Chemical shifts were referenced to external tetramethylsilane (TMS). The reference comprised KH (Aldrich Chemical Company 99%).

<sup>19</sup>K MAS NMR was performed on the blue crystals. The data were recorded on a Bruker DSX-400 spectrometer at 18.67 MHz. Samples were packed in zirconia rotors and sealed with airtight O-ring caps under an inert atmosphere. The MAS frequency was 4.5 kHz. During data acquisition, the sweep width was 125 kHz; the dwell time was 4.0  $\mu$ sec, and the acquisition time was 0.01643 sec/scan. The number of scans was 96. Chemical shifts were referenced to external KBr (Aldrich Chemical Company 99.99%). References comprised KI (Aldrich Chemical Company 99.99%) and KH (Aldrich Chemical Company 99%).

10

#### FTIR Spectroscopy

Samples were transferred to an infrared transmitting substrate and analyzed by FTIR spectroscopy using a Nicolet Magna 550 FTIR Spectrometer with a NicPlan FTIR microscope. The number of scans was 250 for both the sample and background. The resolution was 8.000  $\text{cm}^{-1}$ . A dry air purge was applied.

#### Electrospray-Ionization-Time-Of-Flight-Mass-Spectroscopy (ESITOFMS)

The data was obtained on a Mariner ESI TOF system fitted with a standard electrospray interface. The samples were submitted via a syringe injection system (250  $\mu$ l) with a flow rate of 5.0  $\mu$ l/min. The solvent was water/ethanol (1:1). A reference comprised KI (Aldrich Chemical Company 99.99%).

#### Liquid-Chromatography/Mass-Spectroscopy (LC/MS)

Reverse phase partition chromatography was performed with a PE Sciex API 365 LC/MS/MS System. The column was a LC C18 column, 5.0  $\mu$ m, 150 X 2 mm (Columbus 100 Å Serial #207679). 31.1 mg of blue crystals were dissolved in 6.2 ml solvent of 90% HPLC water and 10% HPLC methanol to give a concentration of 5 mg/ml. The sample was eluted using a gradient technique with the eluents of a solution A (water + 5 mM ammonium acetate + 1% formic acid) and a solution B (acetonitrile/water (90/10) + 5 mM ammonium acetate + 0.1% formic acid). The gradient profile was:

35

Time (min.):	0	3	18	27	28	30
%A	100	100	0	0	100	Stop
%B	0	0	100	100	0	Stop

5 The flow rate was 1 ml/min. The injection volume was 1  $\mu$ l. The pump pressure was 110 PSI.

10 A turbo electrospray ionization (ESI) and triple-quadrupole mass spectrometer was used. The turbo ESI converts the mobile phase to a fine mist of ions. These ions are then separated according to mass in a quadrupole radio frequency electric field. LC/MS provides information comprising 1.) the solute polarity based on the retention time, 2.) quantitative information comprising the concentration based on the chromatogram peak area, and 3.) compound identification based on the mass spectrum or mass to charge ratio of a peak. The mass spectroscopy mode was positive. The selected ion mass to charge ratios (SIM) were 15 m/e = 39.0, 204.8, 370.6, 536.8, and 702.6. The dwell time was 400 ms, and the pause was 2 ms. The turbo gas was 8 L/min. (25 PSI).

20 The controls comprised KI (Aldrich Chemical Company 99.99%) and sample solvent alone.

20

#### Elemental Analysis

25 Elemental analysis was performed by Galbraith Laboratories, Inc., Knoxville, TN. Potassium was determined by Inductively Coupled Plasma using an ICP Optima 3000. Iodide was determined volumetrically by iodometric titration with thiosulfate. The hydrogen was determined by a Perkin-Elmer Elemental Analyzer (#240) using ASTM D-5291 method wherein the sample was combusted in a tube furnace at 950 °C and the water was measured by a thermal conductivity detector. The sample was handled in an inert atmosphere.

30

#### Thermal Decomposition with Analysis by Gas Chromatography

35 The gas cell sample comprised deep blue crystals that changed to white crystals upon exposure to air over about a two week period. 0.5 grams of the sample was placed in a thermal decomposition reactor under an argon atmosphere. The reactor comprised a 1/4" OD by 3" long quartz tube that was sealed at one end and connected at the open end

with Swagelock™ fittings to a T. One end of the T was connected to a needle valve and a Welch Duo Seal model 1402 mechanical vacuum pump. The other end was attached to a septum port. The apparatus was evacuated to between 25 and 50 millitorr. The needle valve was closed 5 to form a gas tight reactor. The sample was heated in the evacuated quartz chamber containing the sample with an external Nichrome wire heater using a Variac transformer. The sample was heated to above 600 °C by varying the transformer voltage supplied to the Nichrome heater until the sample melted and the blue color disappeared. Gas released 10 from the sample was collected with a 500  $\mu$ l gas tight syringe through the septum port and immediately injected into the gas chromatograph. The reactor was cooled to room temperature, and a mixture of white and orange crystalline solid remained.

Gas samples were analyzed with a Hewlett Packard 5890 Series II 15 gas chromatograph equipped with a thermal conductivity detector and a 60 meter, 0.32 mm ID fused silica Rt-Alumina capillary PLOT column (Restek, Bellefonte, PA). The column was conditioned at 200° C for 18-72 hours before each series of runs. Samples were run at -196° C using Ne as the carrier gas. The 60 meter column was run with the carrier gas at 20 3.4 psi with the following flow rates: carrier - 2.0 ml/min, auxiliary - 3.4 ml/min, and reference - 3.5 ml/min, for a total flow rate of 8.9 ml/min. The split rate was 10.0 ml/min.

The control hydrogen gas was ultrahigh purity (MG Industries). Control KI (Aldrich Chemical Company ACS grade, 99+%,) was also treated 25 by the same method as the blue crystals.

#### Thermal Decomposition with Analysis by Mass Spectroscopy

Mass spectroscopy was performed on the gases released from the thermal decomposition of the blue crystals. One end of a 4 mm ID fritted 30 capillary tube containing about 5 mg of sample was sealed with a 0.25 in. Swagelock union and plug (Swagelock Co., Solon, OH). The other end was connected directly to the sampling port of a Dycor System 1000 Quadrapole Mass Spectrometer (Model D200MP, Ametek, Inc., Pittsburgh, PA with a HOVAC Dri-2 Turbo 60 Vacuum System). The capillary was 35 heated with a Nichrome wire heater wrapped around the capillary. The mass spectrum was obtained at the ionization energy of 70 eV and 30 eV

at different sample temperatures in the region  $m/e = 0 - 50$ . With the detection of hydrogen indicated by a  $m/e = 2$  peak, the intensity as a function of time for masses  $m/e = 1$ ,  $m/e = 2$ ,  $m/e = 4$  and  $m/e = 5$  was obtained while changing the ionization potential (IP) of the mass spectrometer from 30 eV to 70 eV.

The control hydrogen gas was ultrahigh purity (MG Industries).

## RESULTS AND DISCUSSION

### ToF-SIMS

The positive ToF-SIMS spectrum obtained from the blue crystals is shown in FIGURE 105. The positive ion spectrum of the blue crystals and that of the *KI* control are dominated by the  $K^+$  ion. The comparison of the positive ToF-SIMS spectrum of the *KI* control with the blue crystals demonstrates that the  $^{39}K^+$  peak of the blue crystals may saturate the detector and give rise to a peak that is atypical of the natural abundance of  $^{41}K$ . The natural abundance of  $^{41}K$  is 6.7%; whereas, the observed  $^{41}K$  abundance from the blue crystals is 73%. The high resolution mass assignment of the  $m/z = 41$  peak of the blue crystals was consistent with  $^{41}K$ , and no peak was observed at  $m/z = 42.98$  ruling out  $^{41}KH_2^+$ . Moreover, the natural abundance of  $^{41}K$  was observed in the positive ToF-SIMS spectra of  $KHCO_3$ ,  $KNO_3$ , and *KI* standards that were obtained with an ion current such that the  $^{39}K$  peak intensity was an order of magnitude higher than that given for the blue crystals. The saturation of the  $^{39}K$  peak of the positive ToF-SIMS spectrum by the blue crystals is indicative of a unique crystalline matrix [*Practical Surface Analysis*, 2nd Edition, Volume 2, Ion and Neutral Spectroscopy, D. Briggs, M. P. Seah (Editors), Wiley & Sons, New York, (1992)].

A  $K^{2+}$  ion was only observed in the positive ion spectrum of the blue crystals.  $Ga^+$   $m/z = 69$ ,  $K_2^+$   $m/z = 78$ ,  $K(KCl)^+$   $m/z = (113)$ ,  $I^+$   $m/z = 127$ ,  $KI^+$   $m/z = 166$ , and a series of positive ions  $K[KI]_n^+$   $m/z = (39 + 166n)$  are also observed.

The negative ion ToF-SIMS of the blue crystals shown in FIGURE 106 was dominated by  $H^-$  and  $I^-$  peaks of about equal intensity. Iodide alone dominated the negative ion ToF-SIMS of the *KI* control. For both,  $O^-$   $m/z = 16$ ,  $OH^-$   $m/z = 17$ ,  $Cl^-$   $m/z = 35$ ,  $KI^-$   $m/z = 166$ , a series of negative ions  $I[KI]_n^-$   $m/z = (127 + 166n)$  are also observed.

XPS

A survey spectrum was obtained over the region  $E_b = 0 \text{ eV}$  to  $1200 \text{ eV}$ .  
5 The primary element peaks allowed for the determination of all of the elements present in the blue crystals and the control *KI*. The survey spectrum also detected shifts in the binding energies of the elements which had implications to the identity of the compound containing the elements.

The XPS survey scan of the blue crystals is shown in FIGURE 107.  
10  $\text{Cl}\text{s}$  at  $284.5 \text{ eV}$  was used as the internal standard for the blue crystals and the control *KI*. The major species present in the blue crystals and the control are potassium and iodide. Trace small amounts of carbonate carbon and oxygen were also identified in the blue crystals. The  $K\text{3p}$  and  $K\text{3s}$  peaks of the blue crystals were shifted relative to those of the control *KI*. The  $K\text{3p}$  and  $K\text{3s}$  of the blue crystals occurred at  $17 \text{ eV}$  and  $33 \text{ eV}$ , respectively. The  $K\text{3p}$  and  $K\text{3s}$  of the control *KI* occurred at  $17.5 \text{ eV}$  and  $33.5 \text{ eV}$ , respectively. Hydrogen is the only element which does not have primary element peaks; thus, it is the only candidate to produce the shifted peaks.  
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20 No elements were present in the survey scan which could be assigned to peaks in the low binding energy region with the exception of the  $K\text{3p}$  and  $K\text{3s}$  peaks at  $17 \text{ eV}$  and  $33 \text{ eV}$ , respectively, the  $O\text{2s}$  at  $23 \text{ eV}$ , and the  $I\text{5s}$ ,  $I\text{4d}_{5/2}$ , and  $I\text{4d}_{3/2}$  peaks at  $12.7 \text{ eV}$ ,  $51 \text{ eV}$ , and  $53 \text{ eV}$ , respectively. Accordingly, any other peaks in this region must be due to novel species. The  $0\text{-}100 \text{ eV}$  binding energy region of a high resolution XPS spectrum of the blue crystals is shown in FIGURE 108. The  $0\text{-}100 \text{ eV}$  binding energy region of a high resolution XPS spectrum of the control *KI* is shown in FIGURE 109. The XPS spectrum of the blue crystals differs from that of *KI* by having additional features at  $9.1 \text{ eV}$  and  $11.1 \text{ eV}$ . The XPS peaks centered at  $9.0 \text{ eV}$  and  $11.1 \text{ eV}$  that do not correspond to any other primary element peaks may correspond to the  $H^-(n=1/4) E_b = 11.2 \text{ eV}$  hydride ion predicted by Mills [R. Mills, *The Grand Unified Theory of Classical Quantum Mechanics*, January 1999 Edition, BlackLight Power, Inc., Cranbury, New Jersey, Distributed by Amazon.com] (Eq. (89)) in two different chemical environments where  $E_b$  is the predicted vacuum binding energy. In this case, the reaction to  
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form  $H^-(n=1/4)$  is given by Eqs. (82-84) and Eq. (88). The hydride ion  $H^-(n=1/2) E_b = 3.05 \text{ eV}$  may also be present in the XPS of the blue crystals under the valance peak at about 3.5 eV. The reaction to form  $H^-(n=1/2)$  is given by Eqs. (85-87) and Eq. (88). Studies to remove iodide followed by XPS are in progress.

### NMR

The  $^1H$  MAS NMR spectra of the control  $KH$  and the blue crystals relative to external tetramethylsilane (TMS) are shown in FIGURE 110 and FIGURE 111, respectively. Three distinguishable resonances at 3.65, 0.13 and -0.26 ppm, respectively, were found in the NMR of  $KH$ . The broad 3.65 ppm peak of  $KH$  is assigned to  $KOH$  formed from air exposure during sample handling. The peaks at 0.13 and -0.26 ppm are assigned to hydride H in different chemical environments.

Three distinguishable resonances at 0.081, -0.376 and -1.209 ppm, respectively, were found in the NMR of the blue crystals. A fourth very broad resonance may be present at -2.5 ppm. The peaks at 0.081 and -0.376 ppm are within the range of  $KH$  and may be ordinary hydride H in two different chemical environments that are distinct from those of the control  $KH$ . The resonances at -1.209 ppm and possibly at -2.5 ppm may be due to novel hydride ions.

The color of the blue crystals was found to change to white over 2 weeks of exposure to air. The color-fade rate was greatly increased upon grinding the blue crystal into a fine powder. A dynamic  $^1H$  NMR study following the possible oxidation or hydrolysis of the blue crystals when exposed to air is shown in FIGURES 112-115. The  $^1H$  MAS NMR spectra from ground blue crystals relative to external tetramethylsilane (TMS) following air exposure times of 1 minute, 20 minutes, 40 minutes, and 60 minutes are shown in FIGURES 112-115. Downfield  $^1H$  resonances shifted gradually to 3.861 and 4.444 ppm and then to 5.789. Upfield resonances shifted to 1.157 ppm, as the exposure to air was prolonged and the blue color concomitantly faded to white. The peak at 5.789 may be due to H of  $KOH$  in a chemical environment that is different from that of  $KOH$  formed by air exposure of  $KH$ . Since the downfield shift of the peak at 5.789 is substantially different from that observed for the control  $KH$ , 3.65 ppm, it may be due to  $KOH$  or a compound comprising  $KOH$  wherein

H is increased binding energy hydrogen. The resonance at 1.157 comprises at least two peaks, one of which has a very broad upfield feature. These peaks may be novel hydride ions which are stable in air. In this case the chemical environment is different from that of the blue 5 crystals which showed potential novel hydride peaks at -1.209 ppm and possibly at -2.5 ppm. These observations strongly suggest that the H species in the blue crystals are new hydride species and may be responsible for the blue color. Decoupling studies are in progress to resolve the broad features of the blue crystal spectrum.

10 The  $^{39}\text{K}$  MAS NMR spectra of  $\text{KH}$ ,  $\text{KI}$ , and the blue crystals each showed a single resonance at 64.56, 52.71, and 53.32 ppm respectively. It is clear that the K local structure in the blue crystals resembles that in  $\text{KI}$ .

### 15 FTIR

The FTIR spectra of  $\text{KI}$  (99.99%) was compared with that of the blue crystals. The FTIR spectra ( $45\text{--}3800\text{ cm}^{-1}$ ) of  $\text{KI}$  is given by Nyquist and Kagel [R. A. Nyquist and R. O. Kagel, *Infrared Spectra of Inorganic Compounds*, Academic Press, New York, (1971), pp. 464-465]. The FTIR 20 spectra ( $500\text{--}4000\text{ cm}^{-1}$ ) of the blue crystals is shown in FIGURE 116. There are no vibrational bands in the  $800\text{--}4000\text{ cm}^{-1}$  region that can usually be assigned to covalent bondings. This eliminates the possibility of  $\text{HI}$  molecule embedded in  $\text{KI}$  crystals, since the H-I stretching mode is not observed at  $\sim 2309\text{ cm}^{-1}$ . The FTIR spectra ( $500\text{--}1500\text{ cm}^{-1}$ ) of the blue 25 crystals is shown in FIGURE 117. Several bands shown in FIGURE 117 such as  $682, 712, 730\text{ cm}^{-1}$  are found in the region assignable to ionic bonding or deformation vibration. The K-H vibrational band may be expected in this region. These bands are not present in pure  $\text{KI}$ . This implies that the compound of the blue crystals is ionic-like and contains 30 different species from  $\text{KI}$ .

### ESITOFMS

The positive ion ESITOFMS spectrum of the blue crystals and that of the  $\text{KI}$  control are dominated by the  $\text{K}^+$  ion. A series of positive ions 35  $\text{K}[\text{KI}]_n$ ,  $m/z = (39 + 166n)$  were also observed. In addition,  $\text{KHI}^+$  was only observed from the blue crystals.

LC/MS

5 No chromatographic peaks were observed of the Selected Ion Monitoring LC/MS analysis of *KI* control and sample solvent alone control.

10 FIGURE 118 is the results of the Selected Ion Monitoring LC/MS analysis of the blue crystals wherein the mass spectrum comprised the  $m/z = 204.6$  ion signal. A chromatographic peak was observed at  $RT = 22.45$  min. which corresponds to a nonpolar compound which gives rise to a  $K(KI)^+$  mass fragment. The LC peak shown in FIGURE 118 at  $RT = 2.21$  min. that comes out with the solvent front after injection corresponds to *KI* that gives rise to mass fragments  $K^+$  and  $K(KI)^+$ .

15 FIGURE 119 is the results of the Selected Ion Monitoring LC/MS analysis of the blue crystals wherein the mass spectrum comprised the  $m/z = 307.6$  ion signal. Chromatographic peaks were observed at  $RT = 11.42$  min. and  $RT = 23.38$  min. which correspond to a nonpolar compounds having the  $K(KI)_2^+$  mass spectrum fragment. The LC peak shown in FIGURE 119 at  $RT = 2.21$  min. that comes out with the solvent front after injection corresponds to *KI* that gives rise to mass fragments  $K^+$  and  $K(KI)_2^+$ .

20 The LC/MS data indicated that the blue crystal comprises a novel compound *KHI* which may contain two different hydride ions which gives rise to different mass fragmentation patterns. One *KHI* compound with a retention time of  $RT = 11.42$  min. may give rise to a  $K(KI)_2^+$  mass fragment. Whereas, a second *KHI* compound with a retention of about  $RT = 23$  min. may give rise to a  $K(KI)^+$  and a  $K(KI)_2^+$  mass fragment.

Gas Chromatography

25 The gas chromatograph of the normal hydrogen gave the retention time for para hydrogen and ortho hydrogen as 22 minutes and 24 minutes, respectively. Control *KI* and *KI* exposed to 500 mtorr of hydrogen at 600 °C in the stainless steel reactor for 48 hours showed no hydrogen release upon heating to above 600 °C with complete melting of the crystals. Dihydriino or hydrogen was released when the blue crystals were heated to above 600 °C with melting which coincided with the loss of the dark blue color of these crystals. The gas chromatograph of the

dihydrino or hydrogen released from the blue crystals when the sample was heated to above 600 °C with melting is shown in FIGURE 120. In previous studies [R. Mills, "NOVEL HYDRIDE COMPOUNDS", PCT US98/14029 filed on July 7, 1998], it was found that hydrogen must be present with dihydrino  $H_2^+ \left[ n = \frac{1}{2}; 2c' = \frac{\sqrt{2}a_0}{2} \right]$  to identify the latter since the migration times are close. But, these results confirm that the blue crystals are a hydride.

### Mass Spectroscopy

10 The dihydrino was identified by mass spectroscopy as a species with a mass to charge ratio of two ( $m/e=2$ ) that has a higher ionization potential than that of normal hydrogen by recording the ion current as a function of the electron gun energy. The intensity as a function of time for masses  $m/e=1$ ,  $m/e=2$ , and  $m/e=3$  obtained while changing the  
15 ionization potential (IP) of the mass spectrometer from 30 eV to 70 eV is shown for gas released from thermal decomposition of the blue crystals and ultrapure hydrogen in FIGURE 121 and FIGURE 122, respectively. Upon increasing the ionization potential from 30 eV to 70 eV, typically the  $m/e=2$  ion current for the blue crystal sample increased by a factor  
20 of about 1000. Under the same pressure conditions, the  $m/e=2$  ion current for the ultrapure hydrogen increased by a factor of less than 2.

The mass spectra ( $m/e=0-50$ ) of the gases released from the thermal decomposition of the blue crystals at an ionization potential of 30 eV and 70 eV were recorded. As the ionization energy was increased  
25 from 30 eV to 70 eV a  $m/e=4$  and a  $m/e=5$  peak were observed that was assigned to  $H_4^+(1/2)$  and  $H_5^+(1/2)$ , respectively. No helium was observed by gas chromatography as given above in gas chromatography section. The peaks serve as a signatures for the presence of dihydrino molecules.

### Elemental Analysis

The quantitative elemental analysis shows that the blue crystal consists of 0.5 wt% H, 22.58 wt% K and 75.40 wt% I, or in equivalent  $KI_{1.028}H_{0.865}$ .

## DISCUSSION

The elemental analysis and the positive and negative ToF-SIMS results of the blue crystals are consistent with the proposed structure *KHI*. The NMR data and the XPS data indicate that two form forms of hydride were observed. The compounds *KI* and *KH* are known wherein the potassium ion is in a +1 state. The structure *KHI* is unknown and extraordinary. The implied valance of potassium is 2+. A  $K^{2+}$  peak was observed in the positive ToF-SIMS which supports 2+ as the valance state. High resolution solids probe magnetic sector mass spectroscopy is in progress to confirm this state. The preliminary results are positive.

Another unusual feature of the blue crystals is its intense dark blue color. Potassium metal my be embedded in *KI* crystals, in which potassium metal ionizes into  $K^+$  and a free electron. This capped free electron may give rise to blue color of the crystals. Therefore, a liquid ammonia solvation experiment was designed to test if there is any *K* metal entrapped in the crystals. Alkali metals are readily soluble in liquid ammonia to give bright blue solutions. In such solutions, the alkali metal ionizes to give a cation  $M^+$  and a quasi-free electron. The free electron is distributed over a cavity in the solvent of radius 300-340 pm formed by displacement of 2-3  $NH_3$  molecules. This species has a broad absorption band extending into the infrared with a maximum of ~1500 nm. It is the short wavelength tail of this band which gives rise to the deep-blue color of the solution.

The blue crystals were dissolved in liquid ammonia. However, the solvation of the blue crystals in liquid ammonia did not produce a blue colored solution. Instead, the blue crystals dissolved with the solution remaining clear. White crystals were recovered after the evaporation of the ammonia. This experiment eliminates the possibility of *K* metal as color center in the blue crystals.

Potassium metal reacts slowly with ethanol to release hydrogen gas. The blue crystals were dissolved in anhydrous ethanol. No gas evolved, and the solution remained clear. This result indicates that the blue color of the crystals may not be due to an impurity, e.g., color center, such as *K* metal in *KI* crystal, since no hydrogen gas was produced. This experiment also eliminates the possibility of *K* metal as color center in the blue crystals.

The blue crystals appear to be an integrated, single compound wherein large amounts of uniform crystals can be prepared. The blue color may be due to the 407 nm continuum of  $H^- (1/2)$  as given by Eq. (89). The thermal decomposition with a release of a hydrogen-type molecule resulted in the loss of the blue color. Thus, the blue color is dependent on the presence of the  $H$  of  $KHI$ . The presence of some  $H^- (1/2)$  is indicated by the thermal decomposition with the identification of a hydrogen-type molecule assigned to  $H_2^{\cdot} \left[ 2c' = \frac{a_v}{\sqrt{2}} \right]$  with an ionization potential of 62 eV (Eq. (92)). Emission spectroscopy with excitation by a plasma source is in progress to determine the presence of  $H^- (1/2)$  emission.

When the blue crystals were pulverized or exposed to air for a prolong period of the order of two weeks the blue faded and white crystals remained. Investigations of the air reaction products are in progress preliminary data indicates that the product is a hydride containing carbon dioxide, oxygen, and water derived species. For example, the positive ToF-SIMS of the air exposed crystals contained three new series of positive ions: {  $K[KH KHCO_3]_n^+$   $m/z = (39 + 140n)$ ,  $K_2OH[KH KHCO_3]_n^+$   $m/z = (95 + 140n)$ , and  $K_3O[KH KHCO_3]_n^+$   $m/z = (133 + 140n)$  }. These ions correspond to inorganic clusters containing novel hydride combinations (i.e.  $KH KHCO_3$  units plus other positive fragments). The negative ion spectrum was dominated by  $O^-$  and  $OH^-$  peaks as well as  $H^-$  and  $I^-$  peaks. A  $KHIO^-$  peak was present only in the negative spectrum of the air exposed blue crystals and not in the spectrum of air exposed  $KI$  control.

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## CONCLUSION

The ToF-SIMS, XPS, NMR, FTIR, ESITOFMS, LC/MS, thermal decomposition with analysis by GC, and MS, and elemental analysis results confirm the identification of  $KHI$  having hydride ions. Two forms of hydride ion may be formed according to Eqs. (84), (87), and (88) which is supported by the XPS, NMR, and LC/MS data. The thermal decomposition with mass spectroscopic analysis indicates that at least  $H^- (1/2)$  is present in  $KHI$  which may be responsible for the blue color. The chemical structure and properties of this compound having a hydride

ion with a high binding energy are indicative of a new field of hydride chemistry. The novel hydride ion may combine with other cations such as other alkali cations and alkaline earth, rare earth, and transition element cations. Numerous novel compounds may be synthesized with 5 extraordinary properties relative to the corresponding compounds having ordinary hydride ions. These novel compounds may have a breath of applications.

CLAIMS

1. A compound comprising
    - (a) at least one neutral, positive, or negative increased binding energy hydrogen species having a binding energy
      - (i) greater than the binding energy of the corresponding ordinary hydrogen species, or
      - (ii) greater than the binding energy of any hydrogen species for which the corresponding ordinary hydrogen species is unstable or is not observed because the ordinary hydrogen species' binding energy is less than thermal energies at ambient conditions, or is negative; and
    - (b) at least one other element.
  
  2. A compound of claim 1 or 2 characterized in that the increased binding energy hydrogen species is selected from the group consisting of  $H_n$ ,  $H_n^-$ , and  $H_n^+$  where n is a positive integer, with the proviso that n is greater than 1 when H has a positive charge.
  
  3. A compound of claim 1 characterized in that the increased binding energy hydrogen species is selected from the group consisting of
    - (a) hydride ion having a binding energy that is greater than the binding of ordinary hydride ion (about 0.8 eV) for  $p=2$  up to 23 in which the binding energy is represented by
$$\text{Binding Energy} = \frac{\hbar^2 \sqrt{s(s+1)}}{8\mu_e a_0^2 \left[ \frac{1 + \sqrt{s(s+1)}}{p} \right]^2} - \frac{\pi \mu_0 e^2 \hbar^2}{m_e^2 a_0^3} \left( 1 + \frac{2^2}{\left[ \frac{1 + \sqrt{s(s+1)}}{p} \right]^3} \right)$$

where  $p$  is an integer greater than one,  $s=1/2$ ,  $\pi$  is pi,  $\hbar$  is Planck's constant bar,  $\mu_0$  is the permeability of vacuum,  $m_e$  is the mass of the electron,  $\mu_e$  is the reduced electron mass,  $a_0$  is the Bohr radius, and  $e$  is the elementary charge; (b) hydrogen atom having a binding energy greater than about 13.6 eV; (c) hydrogen molecule having a first binding energy greater than about 15.5 eV; and (d) molecular hydrogen ion having a binding energy greater than about 16.4 eV.

4. A compound of claim 3 characterized in that the increased binding energy hydrogen species is a hydride ion having a binding energy of about 3.0, 6.6, 11.2, 16.7, 22.8, 29.3, 36.1, 42.8, 49.4, 55.5, 61.0, 65.6, 69.2, 71.5, 72.4, 71.5, 68.8, 64.0, 56.8, 47.1, 34.6, 19.2, or 0.65 eV.

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5. A compound of claim 4 characterized in that the increased binding energy hydrogen species is a hydride ion having the binding energy:

$$\text{Binding Energy} = \frac{\hbar^2 \sqrt{s(s+1)}}{8\mu_e a_0^2 \left[ \frac{1 + \sqrt{s(s+1)}}{p} \right]^2} - \frac{\pi \mu_0 e^2 \hbar^2}{m_e^2 a_0^3} \left( 1 + \frac{2^2}{\left[ \frac{1 + \sqrt{s(s+1)}}{p} \right]^3} \right)$$

10 where  $p$  is an integer greater than one,  $s=1/2$ ,  $\pi$  is pi,  $\hbar$  is Planck's constant bar,  $\mu_0$  is the permeability of vacuum,  $m_e$  is the mass of the electron,  $\mu_e$  is the reduced electron mass,  $a_0$  is the Bohr radius, and  $e$  is the elementary charge.

15 6. A compound of claim 1 characterized in that the increased binding energy hydrogen species is selected from the group consisting of

- (a) a hydrogen atom having a binding energy of about  $\frac{13.6 \text{ eV}}{\left(\frac{1}{p}\right)^2}$

where  $p$  is an integer,

- (b) an increased binding energy hydride ion ( $H^-$ ) having a binding energy of about  $\frac{\hbar^2 \sqrt{s(s+1)}}{8\mu_e a_0^2 \left[ \frac{1 + \sqrt{s(s+1)}}{p} \right]^2} - \frac{\pi \mu_0 e^2 \hbar^2}{m_e^2 a_0^3} \left( 1 + \frac{2^2}{\left[ \frac{1 + \sqrt{s(s+1)}}{p} \right]^3} \right)$  where

20  $s=1/2$ ,  $\pi$  is pi,  $\hbar$  is Planck's constant bar,  $\mu_0$  is the permeability of vacuum,  $m_e$  is the mass of the electron,  $\mu_e$  is the reduced electron mass,  $a_0$  is the Bohr radius, and  $e$  is the elementary charge;

- (c) an increased binding energy hydrogen species  $H_4^+(1/p)$ ;

- (d) an increased binding energy hydrogen species trihydrino molecular ion,  $H_3^+(1/p)$ , having a binding energy of about  $\frac{22.6}{\left(\frac{1}{p}\right)^2} \text{ eV}$  where  $p$  is an integer,

(e) an increased binding energy hydrogen molecule having a binding energy of about  $\frac{15.5}{\left(\frac{1}{p}\right)^2}$  eV ; and

(f) an increased binding energy hydrogen molecular ion with a binding energy of about  $\frac{16.4}{\left(\frac{1}{p}\right)^2}$  eV.

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7. A compound of claim 6 characterized in that p is from 2 to 200.

8. A compound of claim 1 which is greater than 50 atomic percent pure.

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9. A compound of claim 8 which is greater than 90 atomic percent pure.

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10. A compound of claim 9 which is greater than 98 atomic percent pure.

11. A compound of claim 1 characterized in that said increased binding energy hydrogen species is negative.

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12. A compound of claim 11 comprising at least one cation.

13. A compound of claim 12 characterized in that the cation is a proton,  $H_2^+$ ,  $H_3^+$ ,  $H_2^+ \left[ 2c' = \frac{2a_e}{p} \right]^+$ ,  $H_3^+(1/p)$ , or  $H_4^+(1/p)$ .

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14. A compound of claim 1 characterized in that the other element is an ordinary hydrogen atom or an ordinary hydrogen molecule.

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15. A compound of claim 1 having a formula  $[KH_mKCO_3]_n$  characterized in that m and n are each an integer, the compound contains at least one H, and the hydrogen content  $H_m$  of the compound comprises at least one said increased binding energy hydrogen species.

16. A compound of claim 1 having a formula  $[KH_mKNO_3]^{m+} n' X^-$  characterized in that m, m'; n and n' are each an integer, X is a singly negative charged anion, the compound contains at least one H, and the hydrogen content  $H_m$  of the compound comprises at least one said increased binding energy hydrogen species.
- 5 17. A compound of claim 1 having a formula  $[KHKNO_3]_n$  characterized in that n is an integer, and the hydrogen content H of the compound comprises at least one said increased binding energy hydrogen species.
- 10 18. A compound of claim 1 having a formula  $[KHKOH]_n$  characterized in that n is an integer and the hydrogen content H of the compound comprises at least one said increased binding energy hydrogen species.
- 15 19. A compound of claim 1 having a formula  $[MH_mM'X]_n$  characterized in that m and n are each an integer, M and M' are each an alkali or alkaline earth cation, X is a singly or doubly negative charged anion, the compound contains at least one H, and the hydrogen content  $H_m$  of the compound comprises at least one said increased binding energy hydrogen species.
- 20 20. A compound of claim 1 having a formula  $[MH_mM'X]^{m+} n' X^-$  characterized in that m, m', n, and n' are each an integer, M and M' are each an alkali or alkaline earth cation, X and X' are a singly or doubly negative charged anion, the compound contains at least one H, and the hydrogen content  $H_m$  of the compound comprises at least one said increased binding energy hydrogen species.
- 25 21. A compound of claim 1 having a formula  $[MH_mM'X]^{m+} n' M''^{++}$  characterized in that m, m', n, and n' are each an integer, M, M', and M'' are each an alkali or alkaline earth cation, X and X' are each a singly negative charged anion, the compound contains at least one H, and the hydrogen content  $H_m$  of the compound comprises at least one increased binding energy hydrogen species.
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22. A compound of claim 1 having a formula  $[MH_m]^{m+} n' X^-$  characterized in that m, m', n, and n' are each an integer, M is alkali or alkaline earth, organic, organometallic, inorganic, or ammonium cation, X is a singly or doubly negative charged anion, the compound contains at least one H, and the hydrogen content  $H_m$  of the compound comprises at least one increased binding energy hydrogen species.
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23. A compound of claim 1 having a formula  $[MH_m]^{m+} n' M'$  characterized in that m, m', n, and n' are each an integer, M and M' are an alkali or alkaline earth, organic, organometallic, inorganic, or ammonium cation, the compound contains at least one H, and the hydrogen content  $H_m$  of the compound comprises at least one increased binding energy hydrogen species.
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24. A compound of claim 1 having a formula  $M(H_{10})_n$  characterized in that n is an integer, M is other element such as any atom, molecule, or compound, and the hydrogen content  $(H_{10})_n$  of the compound comprises at least one increased binding energy hydrogen species.
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25. A compound of claim 1 having a formula  $M(H_{10})_n$  characterized in that n is an integer, M is an increased binding energy hydrogen compound, and the hydrogen content  $(H_{10})_n$  of the compound comprises at least one increased binding energy hydrogen species.
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26. A compound of claim 1 having a formula  $M^+(H_{16})_n^-$  characterized in that n is an integer, M is other element such as an alkali, organic, organometallic, inorganic, or ammonium cation, and the hydrogen content  $(H_{16})_n^-$  of the compound comprises at least one increased binding energy hydrogen species.
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27. A compound of claim 1 having a formula  $M^+(H_{16})_n^-$  characterized in that n is an integer, M is an increased binding energy hydrogen compound, and the hydrogen content  $(H_{16})_n^-$  of the compound comprises at least one increased binding energy hydrogen species.
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28. A compound of claim 1 having a formula  $M(H_{16})_n$ , characterized in that n is an integer, M is other element such as any atom, molecule, or compound, and the hydrogen content  $(H_{16})_n$  of the compound comprises at least one increased binding energy hydrogen species.
29. A compound of claim 1 having a formula  $M(H_{16})_n$ , characterized in that n is an integer, M is an increased binding energy hydrogen compound, and the hydrogen content  $(H_{16})_n$  of the compound comprises at least one increased binding energy hydrogen species.
30. A compound of claim 1 having a formula  $M(H_{24})_n$ , characterized in that n is an integer, M is other element such as any atom, molecule, or compound, and the hydrogen content  $(H_{24})_n$  of the compound comprises at least one increased binding energy hydrogen species.
31. A compound of claim 1 having a formula  $M(H_{24})_n$ , characterized in that n is an integer, M is an increased binding energy hydrogen compound, and the hydrogen content  $(H_{24})_n$  of the compound comprises at least one increased binding energy hydrogen species.
32. A compound of claim 1 having a formula  $M(H_{60})_n$ , characterized in that n is an integer, M is other element such as any atom, molecule, or compound, and the hydrogen content  $(H_{60})_n$  of the compound comprises at least one increased binding energy hydrogen species.
33. A compound of claim 1 having a formula  $M(H_{60})_n$ , characterized in that n is an integer, M is an increased binding energy hydrogen compound, and the hydrogen content  $(H_{60})_n$  of the compound comprises at least one increased binding energy hydrogen species.
34. A compound of claim 1 having a formula  $M(H_{70})_n$ , characterized in that n is an integer, M is other element such as any atom, molecule, or compound, and the hydrogen content  $(H_{70})_n$  of the compound comprises at least one increased binding energy hydrogen species.

35. A compound of claim 1 having a formula  $M(H_{70})_n$  characterized in that n is an integer, M is an increased binding energy hydrogen compound, and the hydrogen content  $(H_{70})_n$  of the compound comprises at least one increased binding energy hydrogen species.
36. A compound of claim 1 having a formula  $M(H_{10})_q(H_{16})_r(H_{24})_s(H_{60})_t(H_{70})_u$  characterized in that q, r, s, t, and u are each an integer including zero but not all zero, M is other element such as any atom, molecule, or compound, and the hydrogen content  $(H_{10})_q(H_{16})_r(H_{24})_s(H_{60})_t(H_{70})_u$  of the compound comprises at least one increased binding energy hydrogen species.
37. A compound of claim 1 having a formula  $M(H_{10})_q(H_{16})_r(H_{24})_s(H_{60})_t(H_{70})_u$  characterized in that q, r, s, and t are each an integer including zero but not all zero, M is an increased binding energy hydrogen compound, and the hydrogen content  $(H_{10})_q(H_{16})_r(H_{24})_s(H_{60})_t(H_{70})_u$  of the compound comprises at least one increased binding energy hydrogen species.
38. A compound of claim 1 having a formula MX characterized in that M is positive, neutral, or negative and is selected from the list of  $H_{16}$ ,  $H_{16}H$ ,  $H_{16}H_2$ ,  $H_{24}H_{23}$ ,  $OH_{22}$ ,  $OH_{23}$ ,  $OH_{24}$ ,  $MgH_2H_{16}$ ,  $NaH_3H_{16}$ ,  $H_{24}H_2O$ ,  $CNH_{16}$ ,  $CH_{30}$ ,  $SiH_4H_{16}$ ,  $(H_{16})_3H_{15}$ ,  $SiH_4(H_{16})_2$ ,  $(H_{16})_4$ ,  $H_{70}$ ,  $Si_2H_6H_{16}$ ,  $(SiH_4)_2H_{16}$ ,  $SiH_4(H_{16})_3$ ,  $CH_{70}$ ,  $NH_{69}$ ,  $NH_{70}$ ,  $NHH_{70}$ ,  $OH_{70}$ ,  $H_2OH_{70}$ ,  $FH_{70}$ ,  $H_3OH_{70}$ ,  $SiH_2H_{60}$ ,  $Si(H_{16})_3H_{15}$ ,  $Si(H_{16})_4$ ,  $Si_2H_6(H_{16})_2$ ,  $Si_2H_7(H_{16})_2$ ,  $SiH_3(H_{16})_4$ ,  $(SiH_4)_2(H_{16})_2$ ,  $O_2(H_{16})_4$ ,  $SiH_4(H_{16})_4$ ,  $NOH_{70}$ ,  $O_2H_{69}$ ,  $HONH_{70}$ ,  $O_2H_{70}$ ,  $H_2ONH_{70}$ ,  $H_3O_2H_{70}$ ,  $Si_2H_6(H_{24})_2$ ,  $Si_2H_6(H_{16})_3$ ,  $(SiH_4)_3H_{16}$ ,  $(SiH_4)_2(H_{16})_3$ ,  $(OH_{23})H_{16}H_{70}$ ,  $(OH_{24})H_{16}H_{70}$ ,  $Si_3H_{10}(H_{16})_2$ ,  $Si_2H_{70}$ ,  $Si_3H_{11}(H_{16})_2$ ,  $Si_2H_7(H_{16})_4$ ,  $(SiH_4)_3(H_{16})_2$ ,  $(SiH_4)_2(H_{16})_4$ ,  $NaOSiH_2(H_{16})_4$ ,  $NaKHH_{70}$ ,  $Si_2H_7(H_{70})$ ,  $Si_3H_9(H_{16})_3$ ,  $Si_3H_{10}(H_{16})_3$ ,  $Si_2H_6(H_{16})_5$ ,  $(SiH_4)_4H_{16}$ ,  $(SiH_4)_3(H_{16})_3$ ,  $Na_2OSiH_2(H_{16})_4$ ,  $Si_3H_8(H_{16})_4$ ,  $Na_2KHH_{70}$ ,  $Si_3H_9(H_{16})_4$ ,  $Na_2HKHH_{70}$ ,  $SO(H_{16})_6(H_{15})$ ,  $SH_2(OH_{23})H_{16}H_{70}$ ,  $SO(H_{16})_7$ ,  $Mg_2H_2H_{23}H_{16}H_{70}$ ,  $(SiH_4)_4(H_{16})_2$ ,  $(SiH_4)_3(H_{16})_4$ ,  $KH_3O(H_{16})_2H_{70}$ ,  $KH_3O(H_{16})_2H_{70}$ ,  $K(OH_{23})H_{16}H_{70}$ ,  $K_2OH H_{70}$ ,  $NaKHO_2H_{70}$ ,  $NaOHNaO_2 H_{70}$ ,  $HNO_3 O_2 H_{70}$ ,  $Rb(H_{16})_5$ ,  $Si_3H_{11}H_{70}$ ,  $KNO_2(H_{16})_5$ ,  $(SiH_4)_4(H_{16})_3$ ,  $KKH(H_{16})_7$ ,  $(SiH_4)_4(H_{16})_4$ ,  $(KH_2)_2(H_{16})_3H_{70}$ ,  $(NiH_2)_2HCl(H_{16})_2H_{70}$ ,  $Si_5OH_{102}$ ,  $(SiH_3)_7(H_{16})_5$ ,  $Na_3O_3(SiH_3)_{10}SiH(H_{16})_5$ ,

X is other element, and the hydrogen content H of the compound comprises at least one increased binding energy hydrogen.

39. A compound of claim 1 having a formula  $MX$  characterized in that  
 5 M is positive, neutral, or negative and is selected from the list of  $H_{16}$ ,  
 $H_{16}H$ ,  $H_{16}H_2$ ,  $H_{24}H_{23}$ ,  $OH_{22}$ ,  $OH_{23}$ ,  $OH_{24}$ ,  $MgH_2H_{16}$ ,  $NaH_3H_{16}$ ,  $H_{24}H_2O$ ,  $CNH_{16}$ ,  $CH_{30}$ ,  
 $SiH_4H_{16}$ ,  $(H_{16})_3H_{15}$ ,  $SiH_4(H_{16})_2$ ,  $(H_{16})_4$ ,  $H_{70}$ ,  $Si_2H_6H_{16}$ ,  $(SiH_4)_2H_{16}$ ,  $SiH_4(H_{16})_3$ ,  $CH_{70}$ ,  
 $NH_{69}$ ,  $NH_{70}$ ,  $NHH_{70}$ ,  $OH_{70}$ ,  $H_2OH_{70}$ ,  $FH_{70}$ ,  $H_3OH_{70}$ ,  $SiH_2H_{60}$ ,  $Si(H_{16})_3H_{15}$ ,  $Si(H_{16})_4$ ,  
 10  $Si_2H_6(H_{16})_2$ ,  $Si_2H_7(H_{16})_2$ ,  $SiH_3(H_{16})_4$ ,  $(SiH_4)_2(H_{16})_2$ ,  $O_2(H_{16})_4$ ,  $SiH_4(H_{16})_4$ ,  $NOH_{70}$ ,  $O_2H_{69}$ ,  
 $HONH_{70}$ ,  $O_2H_{70}$ ,  $H_2ONH_{70}$ ,  $H_3O_2H_{70}$ ,  $Si_2H_6(H_{24})_2$ ,  $Si_2H_6(H_{16})_3$ ,  $(SiH_4)_3H_{16}$ ,  
 $(SiH_4)_2(H_{16})_3$ ,  $(OH_{23})H_{16}H_{70}$ ,  $(OH_{24})H_{16}H_{70}$ ,  $Si_3H_{10}(H_{16})_2$ ,  $Si_2H_{70}$ ,  $Si_3H_{11}(H_{16})_2$ ,  
 $Si_2H_7(H_{16})_4$ ,  $(SiH_4)_3(H_{16})_2$ ,  $(SiH_4)_2(H_{16})_4$ ,  $NaOSiH_2(H_{16})_4$ ,  $NaKH H_{70}$ ,  $Si_2H_7(H_{70})$ ,  
 $Si_3H_9(H_{16})_3$ ,  $Si_3H_{10}(H_{16})_3$ ,  $Si_2H_6(H_{16})_5$ ,  $(SiH_4)_4H_{16}$ ,  $(SiH_4)_3(H_{16})_3$ ,  $Na_2OSiH_2(H_{16})_4$ ,  
 $Si_3H_8(H_{16})_4$ ,  $Na_2KH H_{70}$ ,  $Si_3H_9(H_{16})_4$ ,  $Na_2HKK H_{70}$ ,  $SO(H_{16})_6(H_{15})$ ,  $SH_2(OH_{23})H_{16}H_{70}$ ,  
 15  $SO(H_{16})_7$ ,  $Mg_2H_2H_{23}H_{16}H_{70}$ ,  $(SiH_4)_4(H_{16})_2$ ,  $(SiH_4)_3(H_{16})_4$ ,  $KH_3O(H_{16})_2H_{70}$ ,  
 $KH_5O(H_{16})_2H_{70}$ ,  $K(OH_{23})H_{16}H_{70}$ ,  $K_2OH H_{70}$ ,  $NaKHO_2H_{70}$ ,  $NaOHNaO_2 H_{70}$ ,  $HNO_3 O_2 H_{70}$ ,  
 $Rb(H_{16})_5$ ,  $Si_3H_{11}H_{70}$ ,  $KNO_2(H_{16})_5$ ,  $(SiH_4)_4(H_{16})_3$ ,  $KKH(H_{16})_7$ ,  $(SiH_4)_4(H_{16})_4$ ,  
 $(KH_2)_2(H_{16})_3H_{70}$ ,  $(NiH_2)_2HCl(H_{16})_2H_{70}$ ,  $Si_5OH_{102}$ ,  $(SiH_3)_7(H_{16})_5$ ,  $Na_3O_3(SiH_3)_{10}SiH(H_{16})_5$ ,  
 X is an increased binding energy hydrogen compound, and the hydrogen  
 20 content H of the compound comprises at least one increased binding  
 energy hydrogen.

40. A compound of claim 1 having a formula  $M(H_x)_n$  characterized in  
 that n is an integer, x is an integer from 8 to 12, M is other element such  
 25 as any atom, molecule, or compound, and the hydrogen content  $(H_x)_n$  of  
 the compound comprises at least one increased binding energy hydrogen  
 species.

41. A compound of claim 1 having a formula  $M(H_x)_n$  characterized in  
 that n is an integer, x is an integer from 8 to 12, M is an increased  
 30 binding energy hydrogen compound, and the hydrogen content  $(H_x)_n$  of  
 the compound comprises at least one increased binding energy hydrogen  
 species.

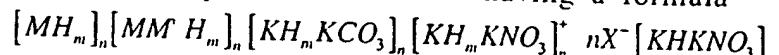
42. A compound of claim 1 having a formula  $M^x(H_x)_n^-$  characterized in that n is an integer, x is an integer from 14 to 18, M is other element such as an alkali, organic, organometallic, inorganic, or ammonium cation, and the hydrogen content  $(H_x)_n^-$  of the compound comprises at least one increased binding energy hydrogen species.
- 5
43. A compound of claim 1 having a formula  $M^x(H_x)_n^-$  characterized in that n is an integer, x is an integer from 14 to 18, M is an increased binding energy hydrogen compound, and the hydrogen content  $(H_x)_n^-$  of the compound comprises at least one increased binding energy hydrogen species.
- 10
44. A compound of claim 1 having a formula  $M(H_x)_n$  characterized in that n is an integer, x is an integer from 14 to 18, M is other element such as any atom, molecule, or compound, and the hydrogen content  $(H_x)_n$  of the compound comprises at least one increased binding energy hydrogen species.
- 15
45. A compound of claim 1 having a formula  $M(H_x)_n$  characterized in that n is an integer, x is an integer from 14 to 18, M is an increased binding energy hydrogen compound, and the hydrogen content  $(H_x)_n$  of the compound comprises at least one increased binding energy hydrogen species.
- 20
46. A compound of claim 1 having a formula  $M(H_x)_n$  characterized in that n is an integer, x is an integer from 22 to 26, M is other element such as any atom, molecule, or compound, and the hydrogen content  $(H_x)_n$  of the compound comprises at least one increased binding energy hydrogen species.
- 25
47. A compound of claim 1 having a formula  $M(H_x)_n$  characterized in that n is an integer, x is an integer from 22 to 26, M is an increased binding energy hydrogen compound, and the hydrogen content  $(H_x)_n$  of the compound comprises at least one increased binding energy hydrogen species.
- 30
- 35

48. A compound of claim 1 having a formula  $M(H_x)_n$  characterized in that n is an integer, x is an integer from 58 to 62, M is other element such as any atom, molecule, or compound, and the hydrogen content  $(H_x)_n$  of 5 the compound comprises at least one increased binding energy hydrogen species.
49. A compound of claim 1 having a formula  $M(H_x)_n$  characterized in that n is an integer, x is an integer from 58 to 62, M is an increased 10 binding energy hydrogen compound, and the hydrogen content  $(H_x)_n$  of the compound comprises at least one increased binding energy hydrogen species.
50. A compound of claim 1 having a formula  $M(H_x)_n$  characterized in 15 that n is an integer, x is an integer from 68 to 72, M is other element such as any atom, molecule, or compound, and the hydrogen content  $(H_x)_n$  of the compound comprises at least one increased binding energy hydrogen species
- 20 51. A compound of claim 1 having a formula  $M(H_x)_n$  characterized in that n is an integer, x is an integer from 68 to 72, M is an increased binding energy hydrogen compound, and the hydrogen content  $(H_x)_n$  of the compound comprises at least one increased binding energy hydrogen species.
- 25 52. A compound of claim 1 having a formula  $M(H_x)_q(H_x)_r(H_y)_s(H_y)_t(H_z)_u$  characterized in that the monomers may be arranged in any order, q, r, s, t, and u are each an integer including zero but not all zero, x is an integer from 8 to 12, x' is an integer from 14 to 18, y is an integer from 22 to 26, 30 y' is an integer from 58 to 62, z is an integer from 68 to 72, M is other element such as any atom, molecule, or compound, and the hydrogen content  $(H_x)_q(H_x)_r(H_y)_s(H_y)_t(H_z)_u$  of the compound comprises at least one increased binding energy hydrogen species.

53. A compound of claim 1 having a formula  $M(H_s)_q(H_r)_t(H_u)_x(H_v)_y(H_w)_z$  characterized in that the monomers may be arranged in any order, q, r, s, t, and u are each an integer including zero but not all zero, x is an integer from 8 to 12, y is an integer from 14 to 18, z is an integer from 22 to 26.
- 5 y' is an integer from 58 to 62, z is an integer from 68 to 72, M is an increased binding energy hydrogen compound, and the hydrogen content  $(H_s)_q(H_r)_t(H_u)_x(H_v)_y(H_w)_z$  of the compound comprises at least one increased binding energy hydrogen species.
- 10 54. A compound of claim 1 having a formula  $[KHKOH]_p[KH_sKOH]_q[KH_KHCO_3]_r[KHCO_3]_s[K_2CO_3]_t$ , characterized in that the monomers may be arranged in any order, p, q, r, s, and t are each an integer including zero but not all zero, the compound contains at least one H, and the hydrogen content H of the compound comprises at least one increased binding energy hydrogen.
- 15 55. A compound of claim 1 having a formula  $[MH_m]_n[MM' H_m]_n[KH_m KCO_3]_n[KH_m KNO_3]^{n'}_n X^- [KHKNO_3]_n$   
 $[KHKOH]_n[MH_m M' X]_n[MH_m M' X']^{m'+}_n n' X^- [MH_m M' X']^{m'-}_n n' M'^+ [MH_m]^{m'+}_n n' X^-$   
 $20 [MH_m]^{m'-}_n n' M'^+ M^+ H_{16}^- [KHKOH]_p[KH_sKOH]_q[KH_KHCO_3]_r[KHCO_3]_s[K_2CO_3]_t$ , characterized in that the monomers may be arranged in any order, n, n', m, m', p, q, r, s, and t are each an integer including zero but not all zero, M, M', and M'' are each an alkali or alkaline earth, organic, organometallic, inorganic, or ammonium cation, X and X' are a singly or doubly negative charged anion, the compound contains at least one H, and the hydrogen content H of the compound comprises at least one increased binding energy hydrogen species.
- 25 56. A compound of claim 1 having a formula  $[MH_m]_n[MM' H_m]_n[KH_m KCO_3]_n[KH_m KNO_3]^{n'}_n X^- [KHKNO_3]_n$   
 $[KHKOH]_n[MH_m M' X]_n[MH_m M' X']^{m'+}_n n' X^- [MH_m M' X']^{m'-}_n n' M'^+ [MH_m]^{m'+}_n n' X^-$   
 $[MH_m]^{m'-}_n n' M'^+ M^+ H_{16}^- [KHKOH]_p[KH_sKOH]_q[KH_KHCO_3]_r[KHCO_3]_s[K_2CO_3]_t$ , M'''(H<sub>10</sub>)<sub>u</sub>(H<sub>16</sub>)<sub>v</sub>(H<sub>24</sub>)<sub>w</sub>(H<sub>60</sub>)<sub>x</sub>(H<sub>70</sub>)<sub>y</sub> characterized in that the monomers may be arranged in any order, n, n', m, m', p, q, r, s, t, q', r', s', t', and u are each

an integer including zero but not all zero, M, M', and M'' are each an alkali or alkaline earth, organic, organometallic, inorganic, or ammonium cation, M''' is other element, X and X' are a singly or doubly negative charged anion, the compound contains at least one H, and the hydrogen content H of the compound comprises at least one increased binding energy hydrogen species.

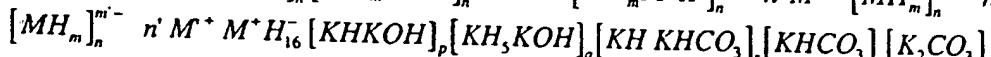
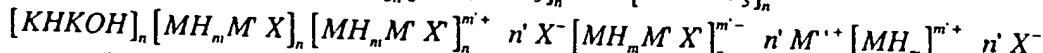
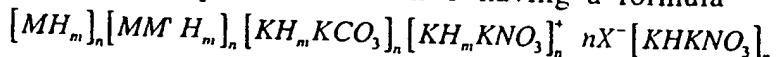
57. A compound of claim 1 having a formula



10  $[KHKOH]_n [MH_m M' X]_n [MH_m M' X]^{m'+} n' X^- [MH_m M' X]^{m'-} n' M'^{++} [MH_m]^{m'+} n' X^-$   
 $[MH_m]^{m'-} n' M^+ M^+ H_{16}^- [KHKOH]_p [KH_5 KOH]_q [KH KHCO_3]_r [KHCO_3]_s [K_2 CO_3]_t$ ,  
 $M'''(H_{10})_q (H_{16})_r (H_{24})_s (H_{60})_t (H_{70})_u$  characterized in that the monomers may be  
arranged in any order, n, n', m, m', p, q, r, s, t, q', r', s', t', and u are each  
15 an integer including zero but not all zero, M, M', and M'' are each an alkali or alkaline earth, organic, organometallic, inorganic, or ammonium cation, M''' is an increased binding energy hydrogen compound, X and X' are a singly or doubly negative charged anion, the compound contains at least one H, and the hydrogen content H of the compound comprises at least one increased binding energy hydrogen species.

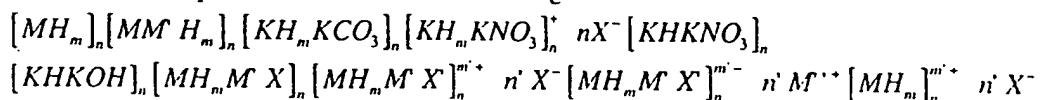
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58. A compound of claim 1 having a formula



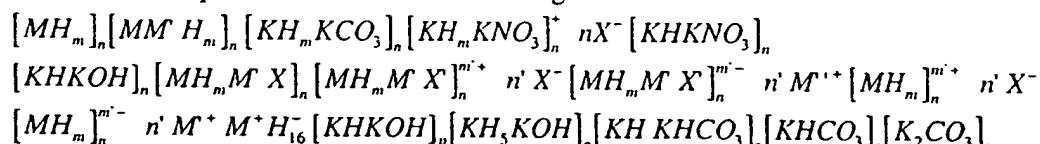
25  $M'''(H_x)_q (H_x)_r (H_y)_s (H_z)_t (H_z)_u$  characterized in that the monomers may be  
arranged in any order, n, n', m, m', p, q, r, s, t, q', r', s', t', and u are each  
an integer including zero but not all zero, x is an integer from 8 to 12, x'  
is an integer from 14 to 18, y is an integer from 22 to 26, y' is an integer  
from 58 to 62, z is an integer from 68 to 72, M, M', and M'' are each an  
30 alkali or alkaline earth, organic, organometallic, inorganic, or ammonium cation, M''' is other element, X and X' are a singly or doubly negative charged anion, the compound contains at least one H, and the hydrogen content H of the compound comprises at least one increased binding energy hydrogen species.

59. A compound of claim 1 having a formula



- 5  $[MH_m]_n^{m'-} n' M'^+ M^+ H_{16}^- [KHKOH]_p [KH_s KOH]_q [KH KHCO_3]_r [KHCO_3]_s [K_2 CO_3]_t$ ,  
 $M'''(H_x)_q (H_x)_r (H_y)_s (H_y)_t (H_z)_u$  characterized in that the monomers may be  
arranged in any order, n, n', m, m', p, q, r, s, t, q', r', s', t', and u are each  
an integer including zero but not all zero, x is an integer from 8 to 12, x'  
is an integer from 14 to 18, y is an integer from 22 to 26, y' is an integer  
10 from 58 to 62, z is an integer from 68 to 72, M, M', and M'' are each an  
alkali or alkaline earth, organic, organometallic, inorganic, or ammonium  
cation, M''' is an increased binding energy hydrogen compound, X and X'  
are a singly or doubly negative charged anion, the compound contains at  
least one H, and the hydrogen content H of the compound comprises at  
15 least one increased binding energy hydrogen species.

60. A compound of claim 1 having a formula



- 20  $M'''(H_x)_q (H_x)_r (H_y)_s (H_y)_t (H_z)_u$  characterized in that the monomers may be  
arranged in any order, n, n', m, m', p, q, r, s, t, q', r', s', t', and u are each  
an integer including zero but not all zero, x is an integer from 8 to 12, x'  
is an integer from 14 to 18, y is an integer from 22 to 26, y' is an integer  
25 from 58 to 62, z is an integer from 68 to 72, M, M' and M'' are each a  
metal such as silicon, aluminum, Group III A elements, Group IVA  
elements, a transition metal, inner transition metal, tin, boron, or a rare  
earth, lanthanide, an alkali or alkaline earth, organic, organometallic,  
inorganic, or ammonium cation, M''' is other element, X and X' are a singly  
30 or doubly negative charged anion, the compound contains at least one H,  
and the hydrogen content H of the compound comprises at least one  
increased binding energy hydrogen species.

61. A compound of claim 1 having a formula  
 $[MH_m]_n [MM' H_n]_n [KH_m KCO_3]_n [KH_m KNO_3]^{n'} nX^- [KHKNO_3]_n$   
 $[KHKOH]_n [MH_m M' X]_n [MH_m M' X']^{m'+} n' X^- [MH_m M' X']^{m'-} n' M''^+ [MH_m]^{m'+} n' X^-$   
 $[MH_m]^{m'-} n' M''^+ M'' H_{16}^- [KHKOH]_p [KH_3 KOH]_q [KH_3 KHCO_3]_r [KHCO_3]_s [K_2 CO_3]_t$
- 5       $M''(H_x)_q (H_x)_r (H_y)_s (H_z)_u$  characterized in that the monomers may be arranged in any order, n, n', m, m', p, q, r, s, t, q', r', s', t', and u are each an integer including zero but not all zero, x is an integer from 8 to 12, x' is an integer from 14 to 18, y is an integer from 22 to 26, y' is an integer from 58 to 62, z is an integer from 68 to 72, M, M' and M'' are each a metal such as silicon, aluminum, Group III A elements, Group IVA elements, a transition metal, inner transition metal, tin, boron, or a rare earth, lanthanide, an alkali or alkaline earth, organic, organometallic, inorganic, or ammonium cation, M''' is an increased binding energy hydrogen compound, X and X' are a singly or doubly negative charged anion, the compound contains at least one H, and the hydrogen content H of the compound comprises at least one increased binding energy hydrogen species.
- 10
- 15
62. A compound of claim 1 having a formula  $Si_x H_y (H_{16})_z$  characterized in that x is an integer, y is an integer from  $2x+2$  to  $4x$ , z is an integer, and the hydrogen content H of the compound comprises at least one increased binding energy hydrogen species.
- 20
63. A compound of claim 16 characterized in that said singly negative charged anion is selected from the group consisting of halogen ions, hydroxide ion, hydrogen carbonate ion, dihydrogen phosphate, and nitrate ion.
- 25
64. A compound of claim 19 characterized in that said singly negative charged anion is selected from the group consisting of halogen ion, hydroxide ion, hydrogen carbonate ion, dihydrogen phosphate, and nitrate ion.
- 30
65. A compound of claim 20 characterized in that said singly negative charged anion is selected from the group consisting of halogen ion,
- 35

hydroxide ion, hydrogen carbonate ion, dihydrogen phosphate, and nitrate ion.

66. A compound of claim 21 characterized in that said singly negative 5 charged anion is selected from the group consisting of halogen ions, hydroxide ion, hydrogen carbonate ion, dihydrogen phosphate, and nitrate ion.

67. A compound of claim 22 characterized in that said singly negative 10 charged anion is selected from the group consisting of halogen ion, hydroxide ion, hydrogen carbonate ion, dihydrogen phosphate, and nitrate ion.

68. A compound of claim 55 characterized in that said singly negative 15 charged anion is selected from the group consisting of halogen ions, hydroxide ion, hydrogen carbonate ion, dihydrogen phosphate, and nitrate ion.

69. A compound of claim 56 characterized in that said singly negative 20 charged anion is selected from the group consisting of halogen ion, hydroxide ion, hydrogen carbonate ion, dihydrogen phosphate, and nitrate ion.

70. A compound of claim 57 characterized in that said singly negative 25 charged anion is selected from the group consisting of halogen ion, hydroxide ion, hydrogen carbonate ion, dihydrogen phosphate, and nitrate ion.

71. A compound of claim 58 characterized in that said singly negative 30 charged anion is selected from the group consisting of halogen ions, hydroxide ion, hydrogen carbonate ion, dihydrogen phosphate, and nitrate ion.

72. A compound of claim 59 characterized in that said singly negative 35 charged anion is selected from the group consisting of halogen ions,

hydroxide ion, hydrogen carbonate ion, dihydrogen phosphate, and nitrate ion.

5 73. A compound of claim 60 characterized in that said singly negative charged anion is selected from the group consisting of halogen ions, hydroxide ion, hydrogen carbonate ion, dihydrogen phosphate, and nitrate ion.

10 74. A compound of claim 61 characterized in that said singly negative charged anion is selected from the group consisting of halogen ion, hydroxide ion, hydrogen carbonate ion, dihydrogen phosphate, and nitrate ion.

15 75. A compound of claim 19 characterized in that said doubly negative charged anion is selected from the group consisting of carbonate ion, oxides, phosphates, hydrogen phosphates, and sulfate ion.

20 76. A compound of claim 20 characterized in that said doubly negative charged anion is selected from the group consisting of carbonate ion, oxides, phosphates, hydrogen phosphates, and sulfate ion

25 77. A compound of claim 22 characterized in that said doubly negative charged anion is selected from the group consisting of carbonate ion, oxides, phosphates, hydrogen phosphates, and sulfate ion

78. A compound of claim 55 characterized in that said doubly negative charged anion is selected from the group consisting of carbonate ion, oxides, phosphates, hydrogen phosphates, and sulfate ion

30 79. A compound of claim 56 characterized in that said doubly negative charged anion is selected from the group consisting of carbonate ion, oxides, phosphates, hydrogen phosphates, and sulfate ion

35 80. A compound of claim 57 characterized in that said doubly negative charged anion is selected from the group consisting of carbonate ion, oxides, phosphates, hydrogen phosphates, and sulfate ion

81. A compound of claim 58 characterized in that said doubly negative charged anion is selected from the group consisting of carbonate ion, oxides, phosphates, hydrogen phosphates, and sulfate ion

5

82. A compound of claim 59 characterized in that said doubly negative charged anion is selected from the group consisting of carbonate ion, oxides, phosphates, hydrogen phosphates, and sulfate ion

10 83. A compound of claim 60 characterized in that said doubly negative charged anion is selected from the group consisting of carbonate ion, oxides, phosphates, hydrogen phosphates, and sulfate ion

15 84. A compound of claim 61 characterized in that said doubly negative charged anion is selected from the group consisting of carbonate ion, oxides, phosphates, hydrogen phosphates, and sulfate ion

85. A compound comprising

- (a) at least one neutral, positive, or negative increased binding energy hydrogen species having a total energy
- 20 (i) greater than the total energy of the corresponding ordinary hydrogen species, or
- (ii) greater than the total energy of any hydrogen species for which the corresponding ordinary hydrogen species is unstable or is not observed because the ordinary hydrogen species' total energy is less than thermal energies at ambient conditions, or is negative; and
- 25 (b) at least one other element.

30 86. A method of separating a desired isotope from a mixture of isotopes:

reacting an increased binding energy hydrogen species with an isotopic mixture comprising a molar excess of a desired isotope with respect to the increased binding energy hydrogen species to form a compound enriched in the desired isotope;

35 separating said compound enriched in the desired isotope from the reaction mixture; and

separating the increased binding energy hydrogen species from the desired isotope to obtain the desired isotope.

- 5 87. A method of separating a desired isotope from a mixture of isotopes:
- reacting a mixture of isotopes with an increased binding energy hydrogen species, and
- removing said compound enriched in the undesired isotope.
- 10 88. The method of claim 86 characterized in that the mixture of isotopes comprises elements and/or compounds containing the isotopes.
- 15 89. The method of claim 87 characterized in that the mixture of isotopes comprises elements and/or compounds containing the isotopes.
90. A method of separating isotopes according to any of claims 86-89 characterized in that the increased binding energy hydrogen species is an increased binding energy hydride ion.
- 20 91. A method of separating isotopes according to claim 86, further comprising the steps of repeating said steps of reacting and separating until a desired level or enrichment is obtained.
- 25 92. A method of separating isotopes according to claim 87, characterized in that said increased binding energy hydrogen species is added in an amount less than the stoichiometric amount to fully react with said undesired isotope.
- 30 93. A method of separating isotopes according to claim 92, further comprising the steps of repeating said steps of reacting and removing until a desired level of enrichment is obtained.
- 35 94. A method of separating isotopes according to claim 87, characterized in that said increased binding energy hydrogen species is added in about the stoichiometric amount to fully react with said undesired isotope.

95. The compound of claim 1 that is a source of protons when thermally decomposed.

5 96. The compound of claim 1 that can be statically charged and comprises a component of a xerographic toner.

97. The compound of claim 1 that may be useful as a magnet or may comprise a magnetic computer memory storage material.

10

98. The hydrino atom of claim 1 that comprises an etching agent.

99. A method of forming the novel compounds of claim 1 comprising the steps of:

15

providing a gaseous catalyst comprising at least one selected from the group consisting of atoms of Li, Be, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Kr, Rb, Sr, Nb, Mo, Pd, Sn, Te, Cs, Ce, Pr, Sm, Gd, Dy, Pb, and Pt;

providing gaseous hydrogen atoms;

20

reacting said gaseous catalyst with said gaseous hydrogen atoms, thereby forming hydrino from said gaseous hydrogen atoms;

reacting said hydrino with at least one selected from the group of a source of electrons,  $H^+$ , increased binding energy hydrogen species, and other element to form said novel compounds.

25

100. A method of claim 99 of forming novel compounds characterized in that a gaseous catalysts comprises at least one selected from the group consisting of a source of  $K^+$ , a source of  $Rb^+$ , and a source of  $He^+$ .

30

101. A method of claim 100 of forming novel compounds characterized in that the source of  $K^+$  is potassium metal.

35

102. A method of claim 100 of forming novel compounds characterized in that the source of  $Rb^+$  is rubidium metal.

103. A method of claim 99 of forming novel compounds further comprising the step of applying an adjustable electric or magnetic field to control the rate of formation of hydrino.

5 104. A method for extracting energy from hydrogen atoms comprising the steps of:

providing a gaseous catalyst comprising at least one selected from the group consisting of atoms of Li, Be, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Kr, Rb, Sr, Nb, Mo, Pd, Sn, Te, Cs, Ce, Pr, Sm, Gd, Dy, Pb, and Pt;

providing gaseous hydrogen atoms; and

reacting said gaseous catalyst with said gaseous hydrogen atoms, thereby releasing energy from said gaseous hydrogen atoms.

15

105. A method of claim 104 for extracting energy from hydrogen atoms characterized in that a gaseous catalysts comprises at least one selected from the group consisting of a source of  $K^+$ , a source of  $Rb^+$ , and a source of  $He^+$ .

20

106. A method of claim 105 for extracting energy from hydrogen atoms characterized in that the source of  $K^+$  is potassium metal.

25

107. A method of claim 105 for extracting energy from hydrogen atoms characterized in that the source of  $Rb^+$  is rubidium metal.

30

108. A method of claim 104 for extracting energy from hydrogen atoms further comprising the step of applying an adjustable electric or magnetic field to control the rate of energy release.

35

109. A cell for extracting energy from hydrogen atoms comprising:  
a reaction vessel;  
a source of gaseous hydrogen atoms; and  
a source of a gaseous catalyst comprising at least one selected from the group consisting of atoms of Li, Be, K, Ca, Ti,

V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Kr, Rb, Sr, Nb, Mo, Pd, Sn, Te, Cs, Ce, Pr, Sm, Gd, Dy, Pb, and Pt.

110. A cell of claim 109 for extracting energy from hydrogen atoms  
5 characterized in that a gaseous catalyst comprises at least one selected from the group consisting of a source of  $K^+$ , a source of  $Rb^+$ , and a source of  $He^+$ .

111. A cell of claim 110 for extracting energy from hydrogen atoms  
10 characterized in that the source of  $K^+$  is potassium metal.

112. A cell of claim 110 for extracting energy from hydrogen atoms characterized in that the source of  $Rb^+$  is rubidium metal.

113. A cell of claim 109 for extracting energy from hydrogen atoms further comprising an adjustable electric or magnetic field source.

114. A cell for extracting energy from hydrogen atoms comprising:  
a reaction vessel;  
20 a chamber communicating with said vessel, said chamber containing gaseous hydrogen atoms or a source of said hydrogen atoms; and  
a catalyst reservoir communicating with said reaction vessel or a boat contained in said reaction vessel, said catalyst reservoir or boat containing a gaseous catalyst comprising at least one selected from the group consisting of atoms of Li, Be, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Kr, Rb, Sr, Nb, Mo, Pd, Sn, Te, Cs, Ce, Pr, Sm, Gd, Dy, Pb, and Pt.

115. A cell of claim 114 for extracting energy from hydrogen atoms characterized in that a gaseous catalyst comprises at least one selected from the group consisting of a source of  $K^+$ , a source of  $Rb^+$ , and a source of  $He^+$ .

116. A cell of claim 115 for extracting energy from hydrogen atoms characterized in that the source of  $K^+$  is potassium metal.

117. A cell of claim 115 for extracting energy from hydrogen atoms characterized in that the source of  $Rb^+$  is rubidium metal.
- 5 118. A cell of claim 114 for extracting energy from hydrogen atoms further comprising an adjustable electric or magnetic field source.

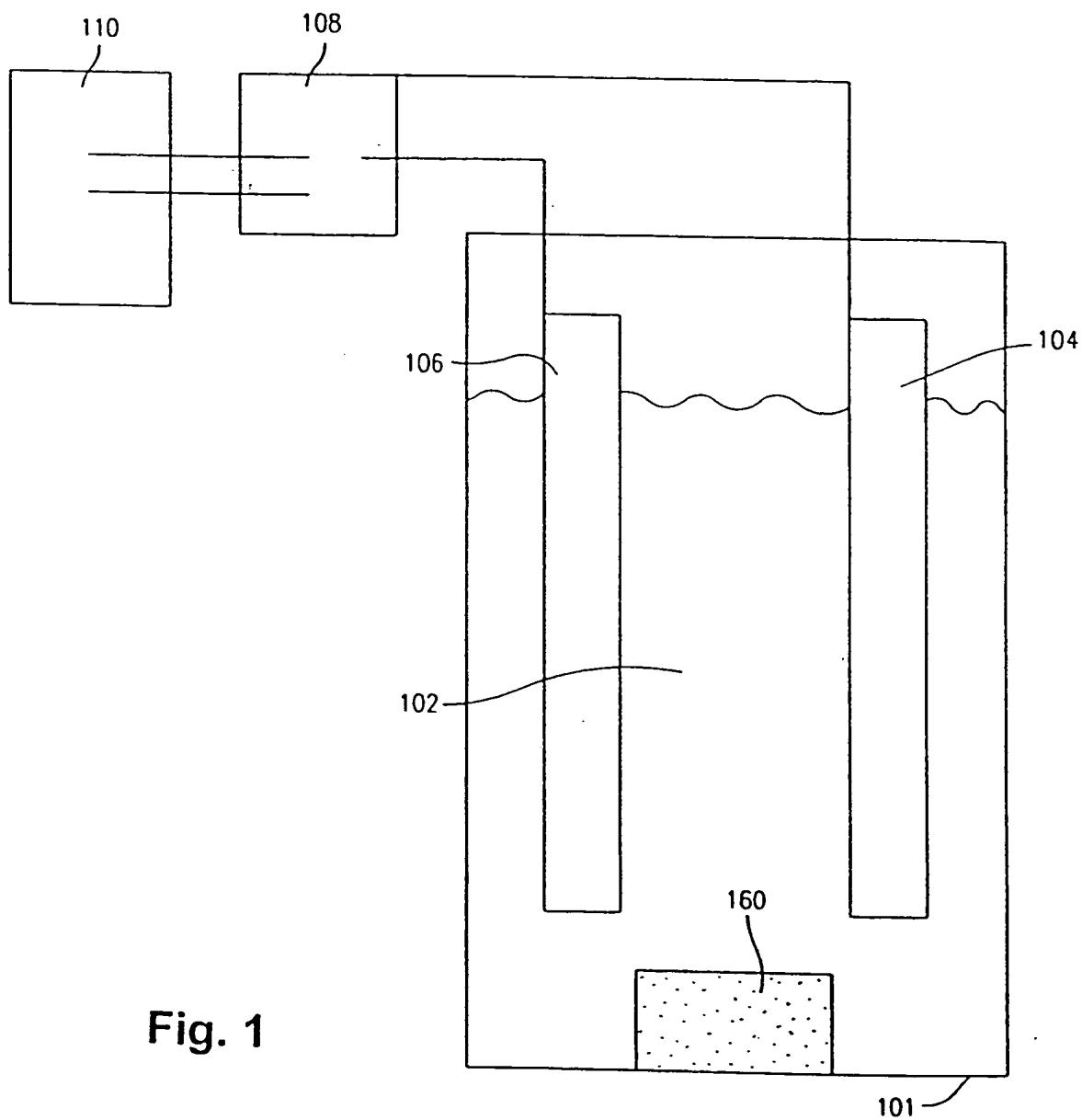


Fig. 1

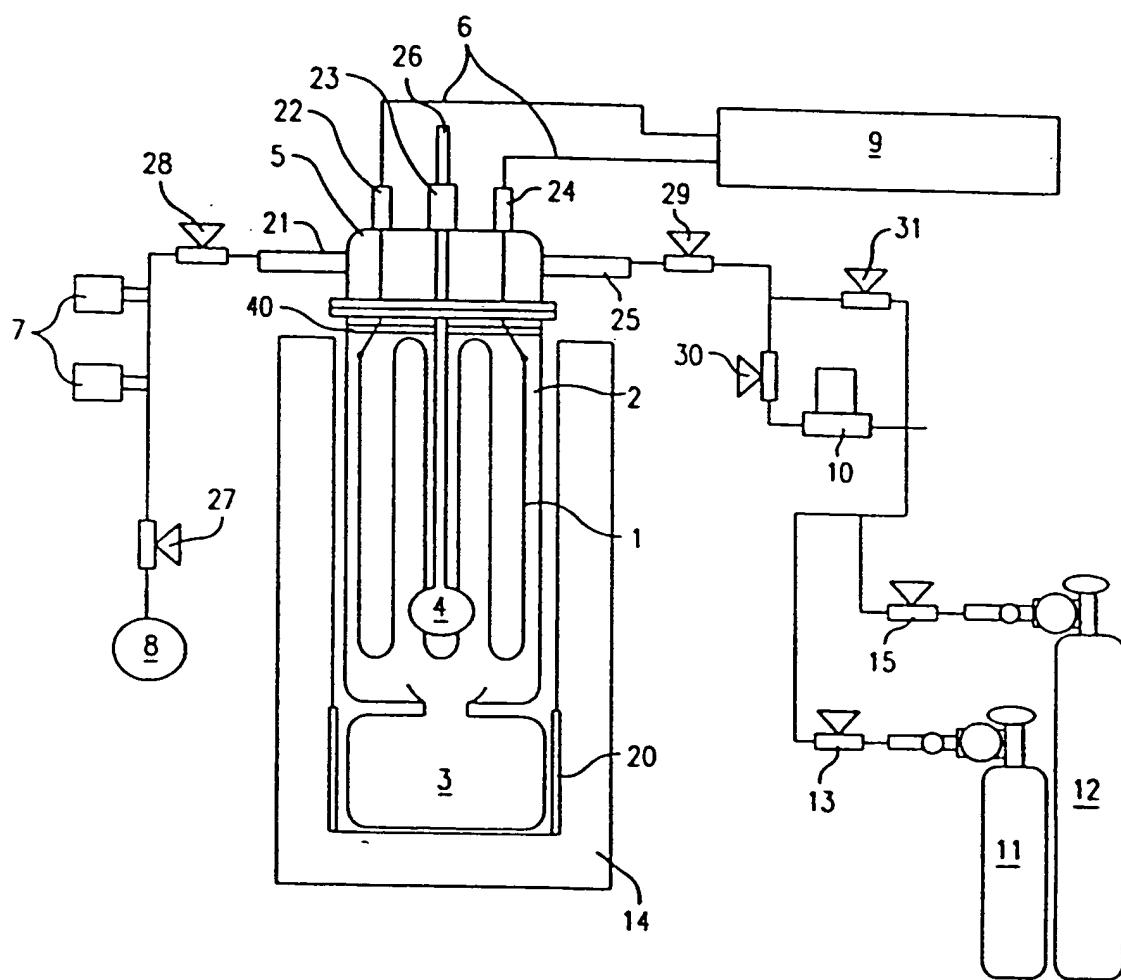


Fig. 2

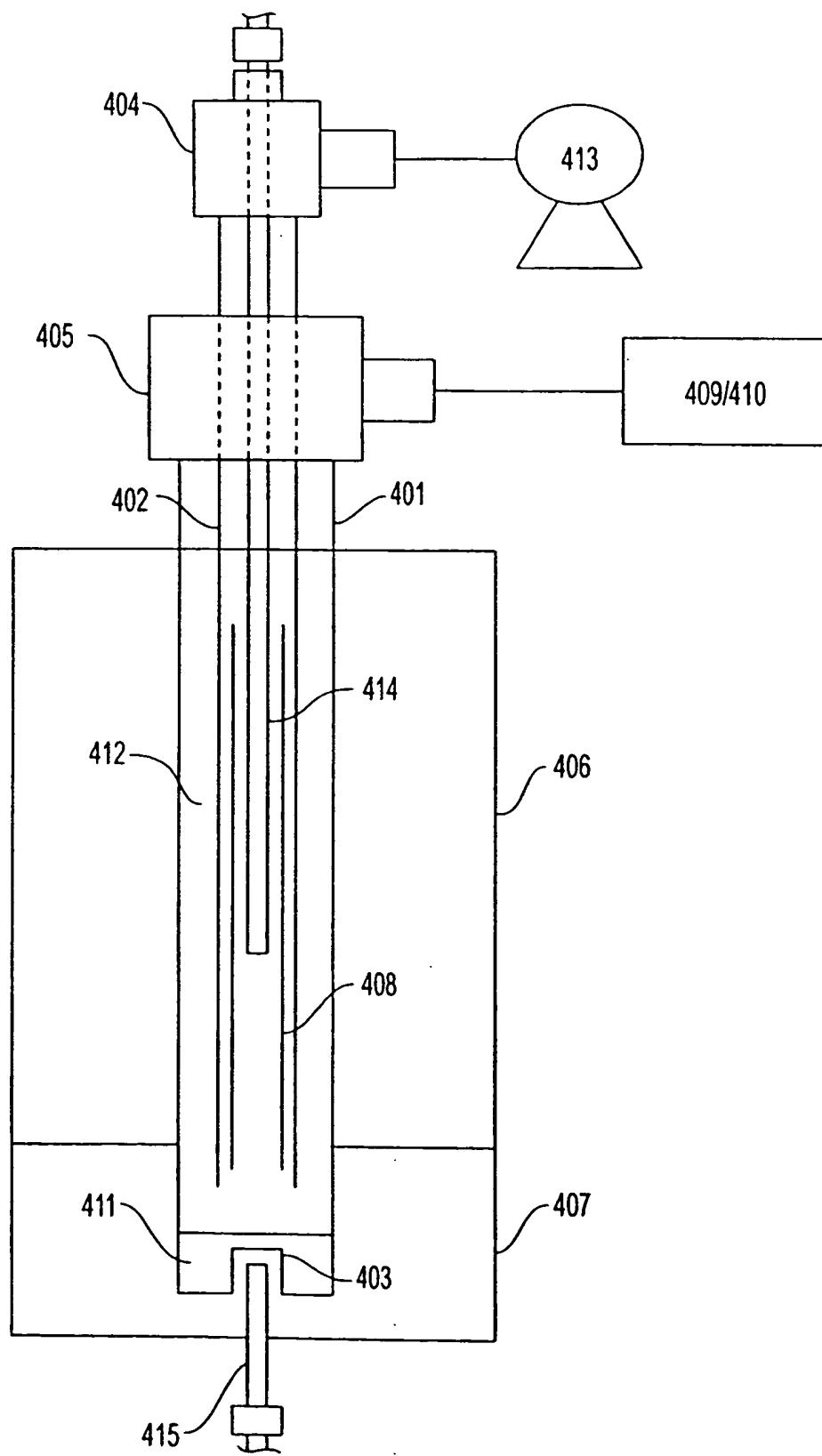


FIG. 3

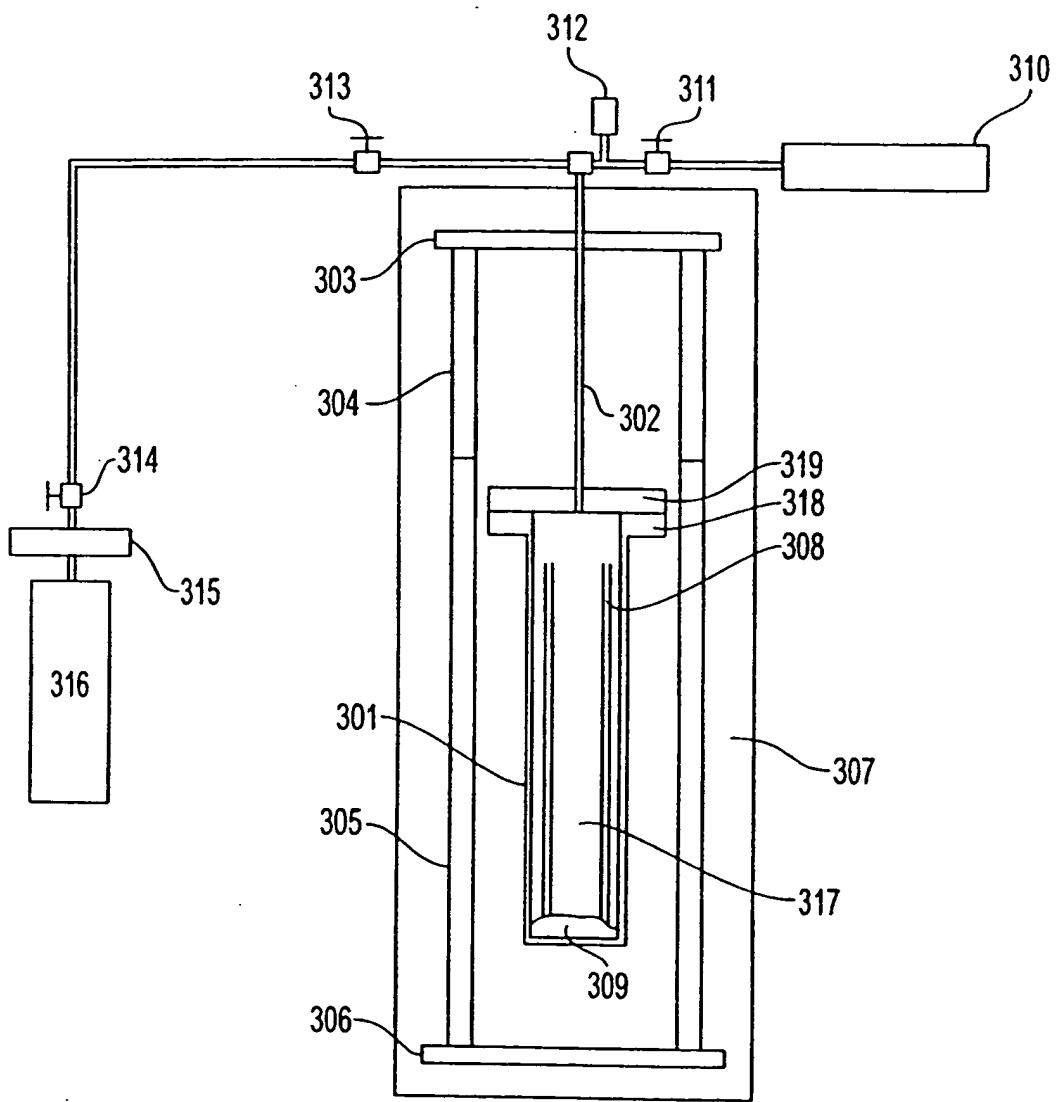


FIG. 4

FIG. 96A

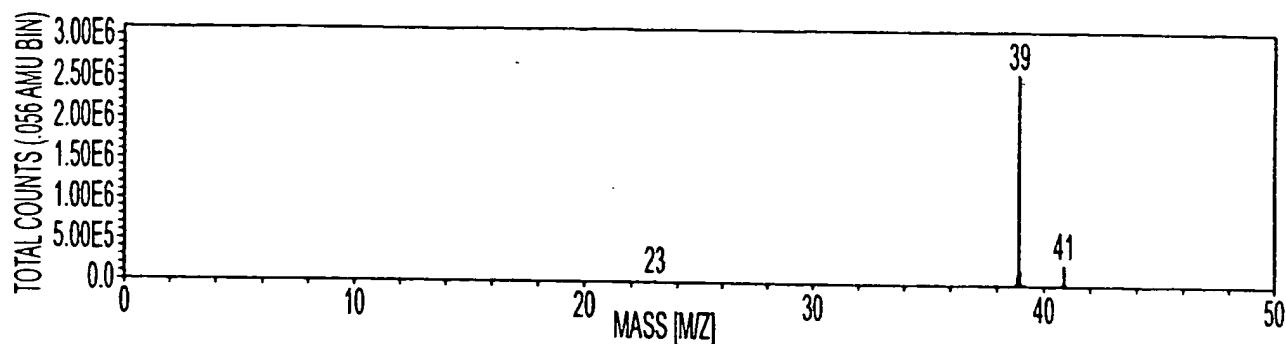


FIG. 96B

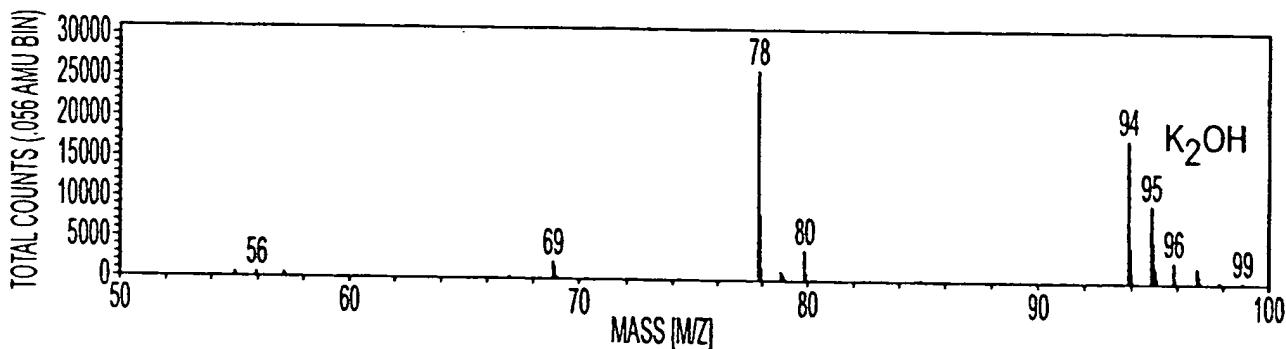


FIG. 96C

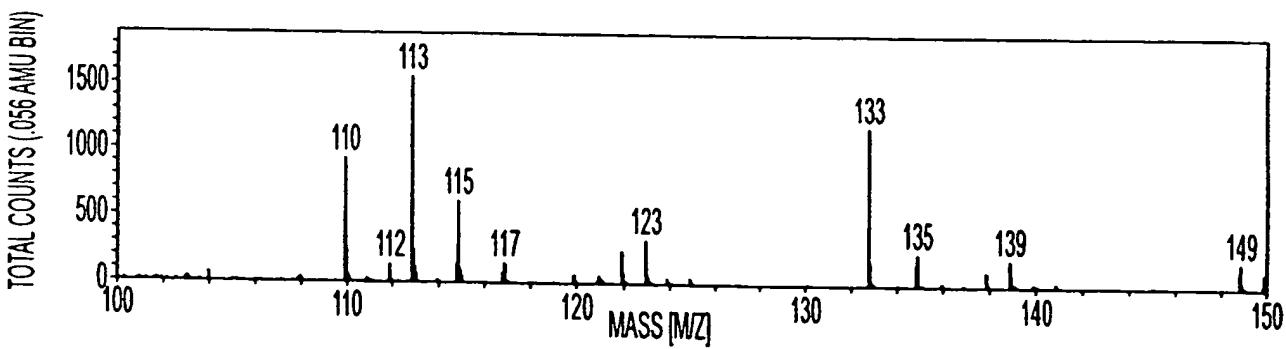


FIG. 96D

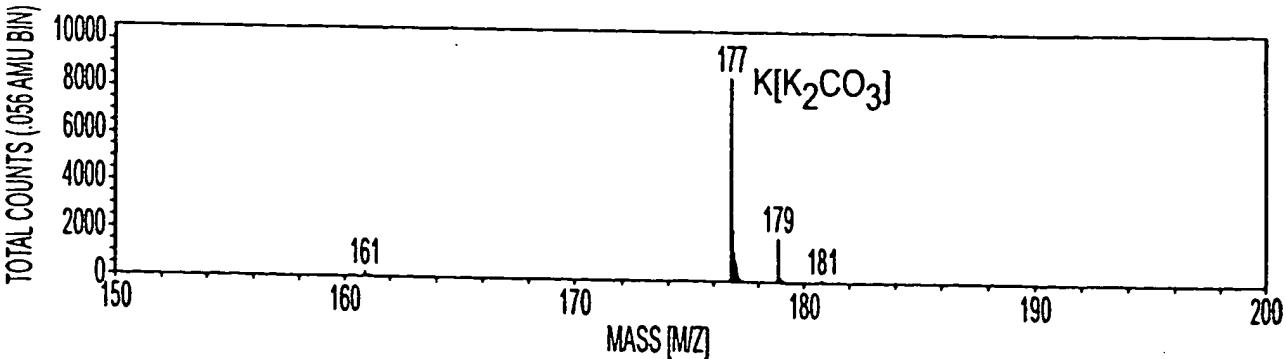


FIG. 97A

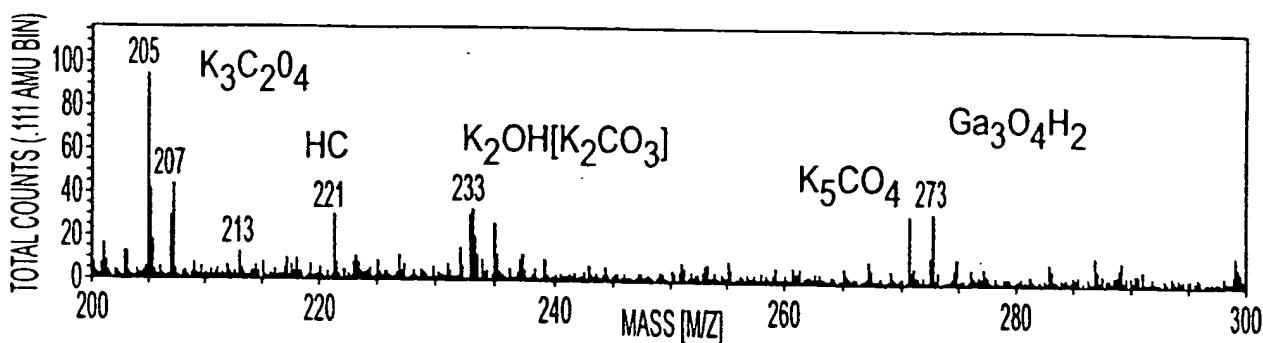


FIG. 97B

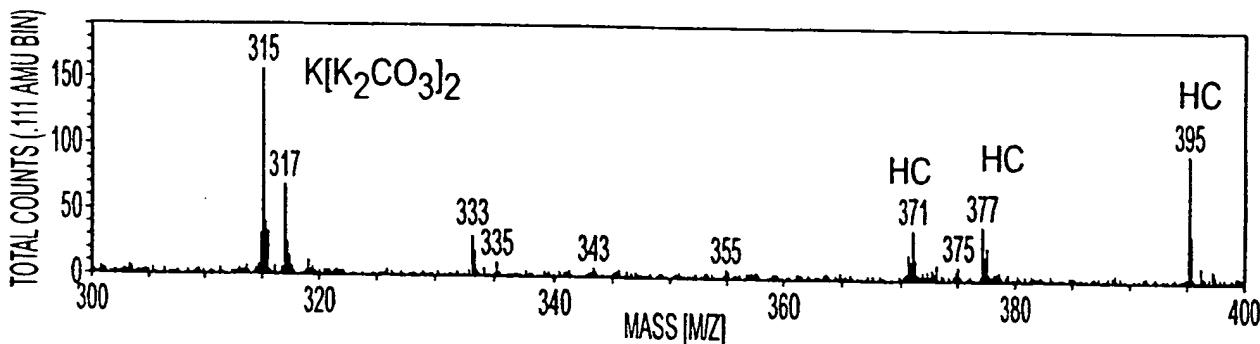


FIG. 97C

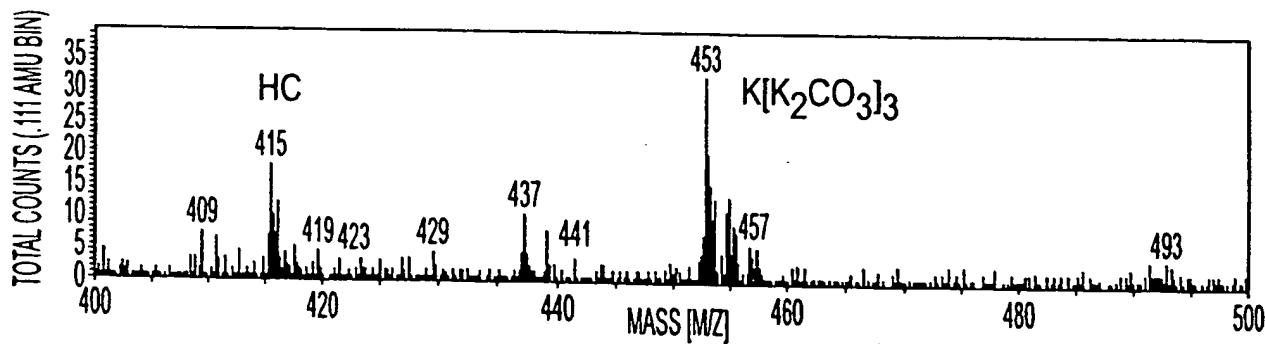


FIG. 97D

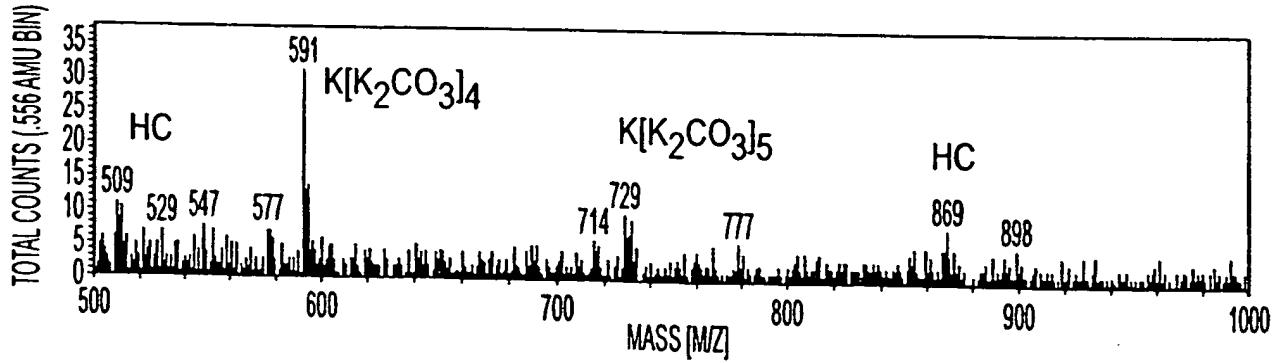


FIG. 98A

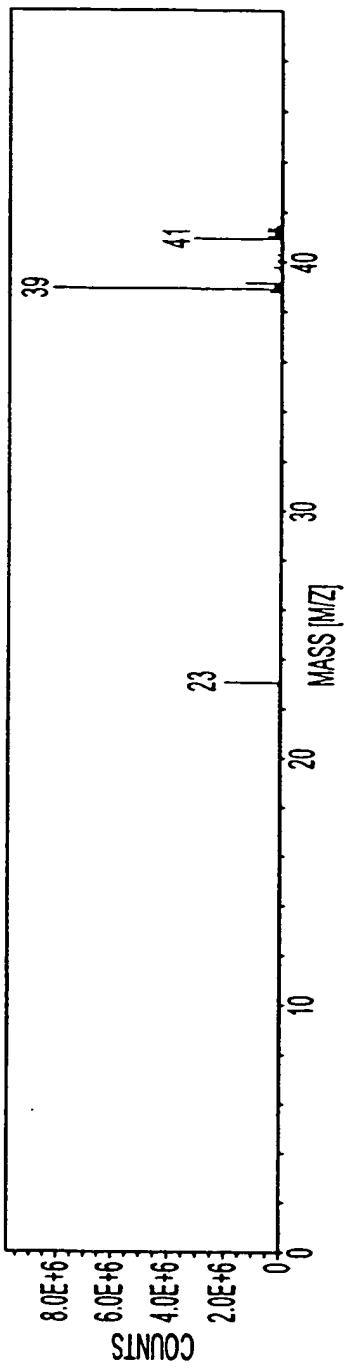


FIG. 98B

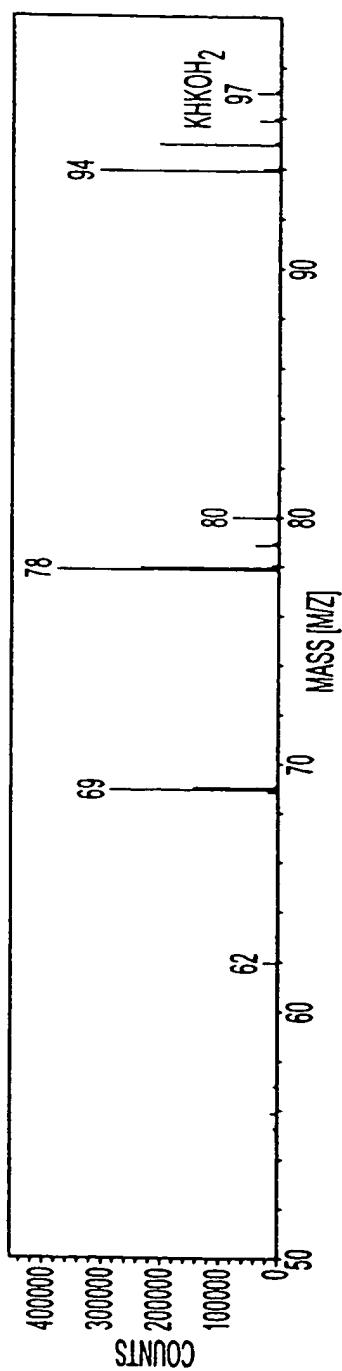


FIG. 98C

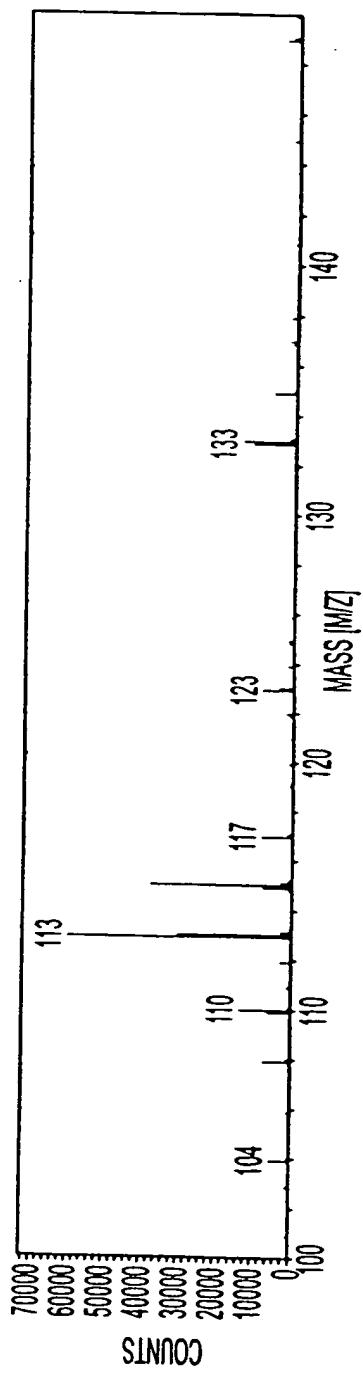


FIG. 98D

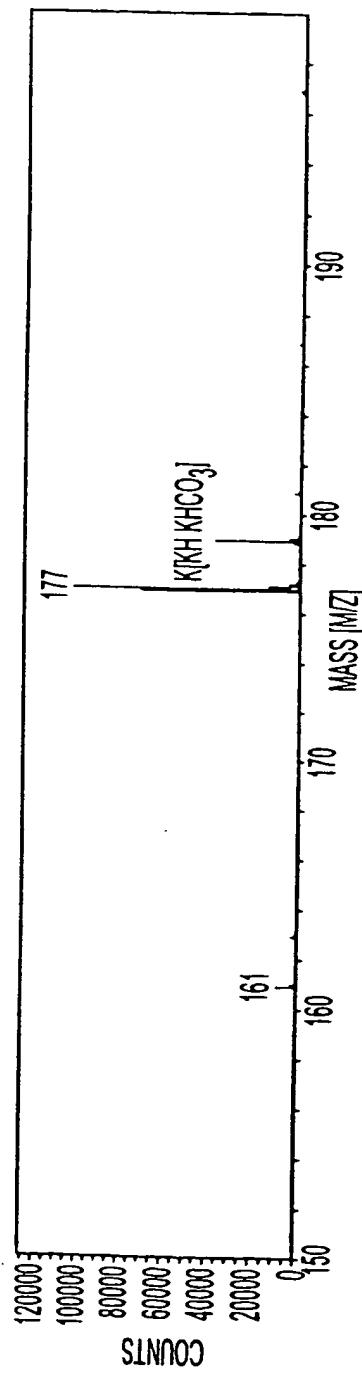


FIG. 99A

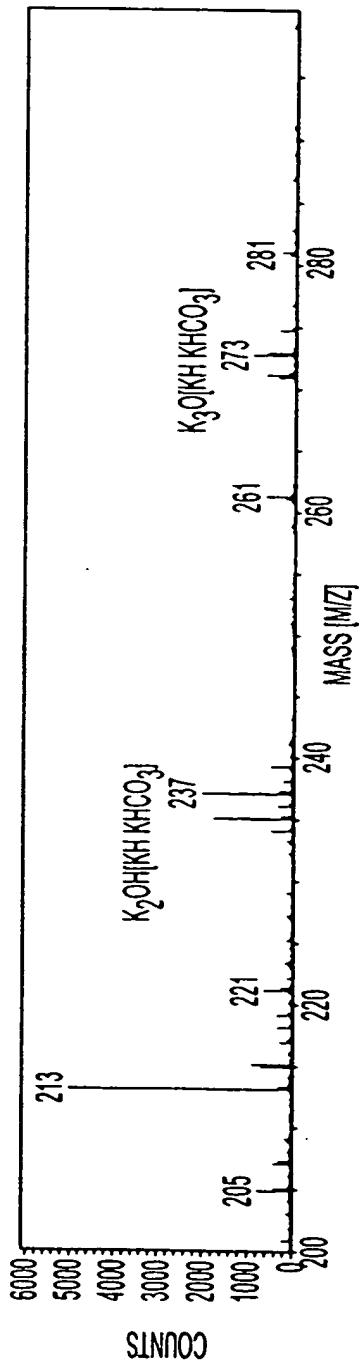


FIG. 99B

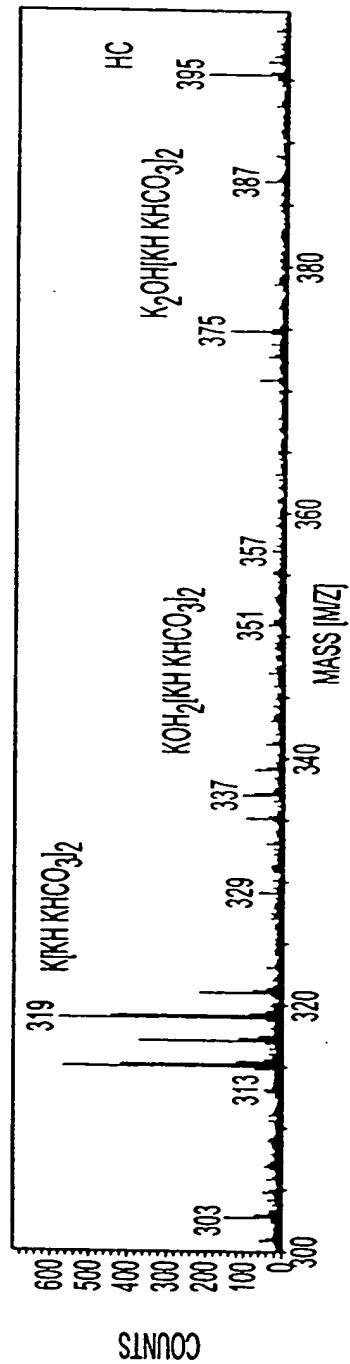


FIG. 99C

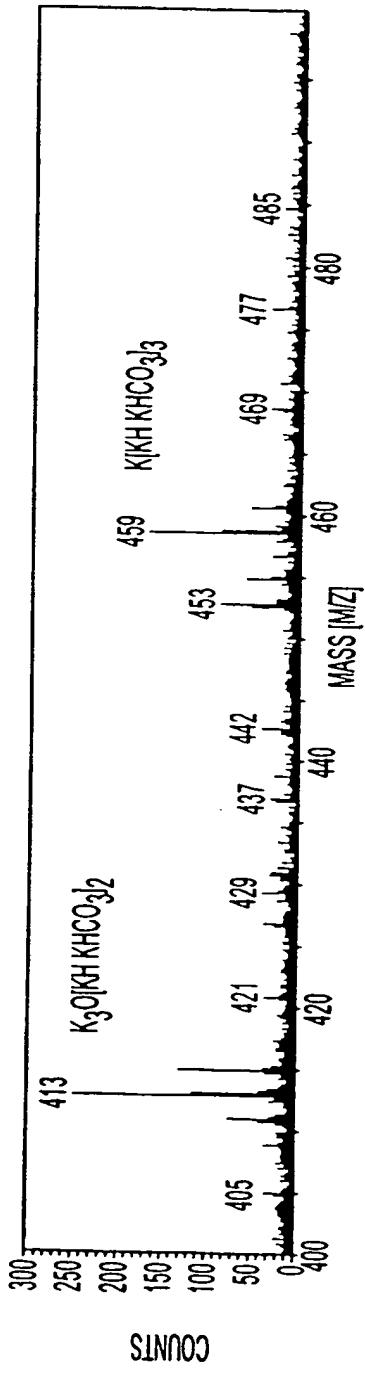
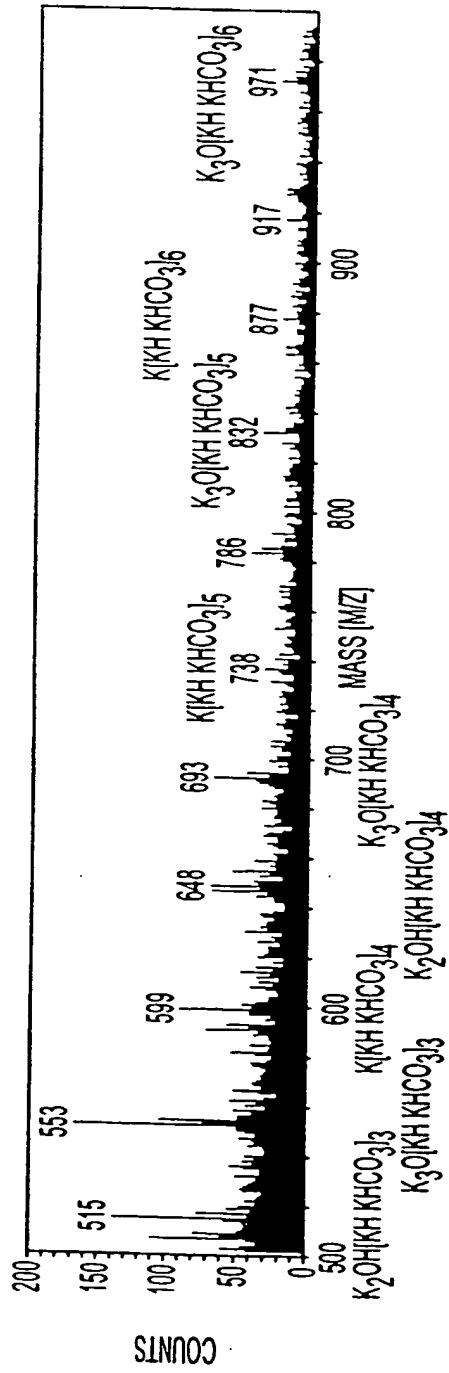


FIG. 99D



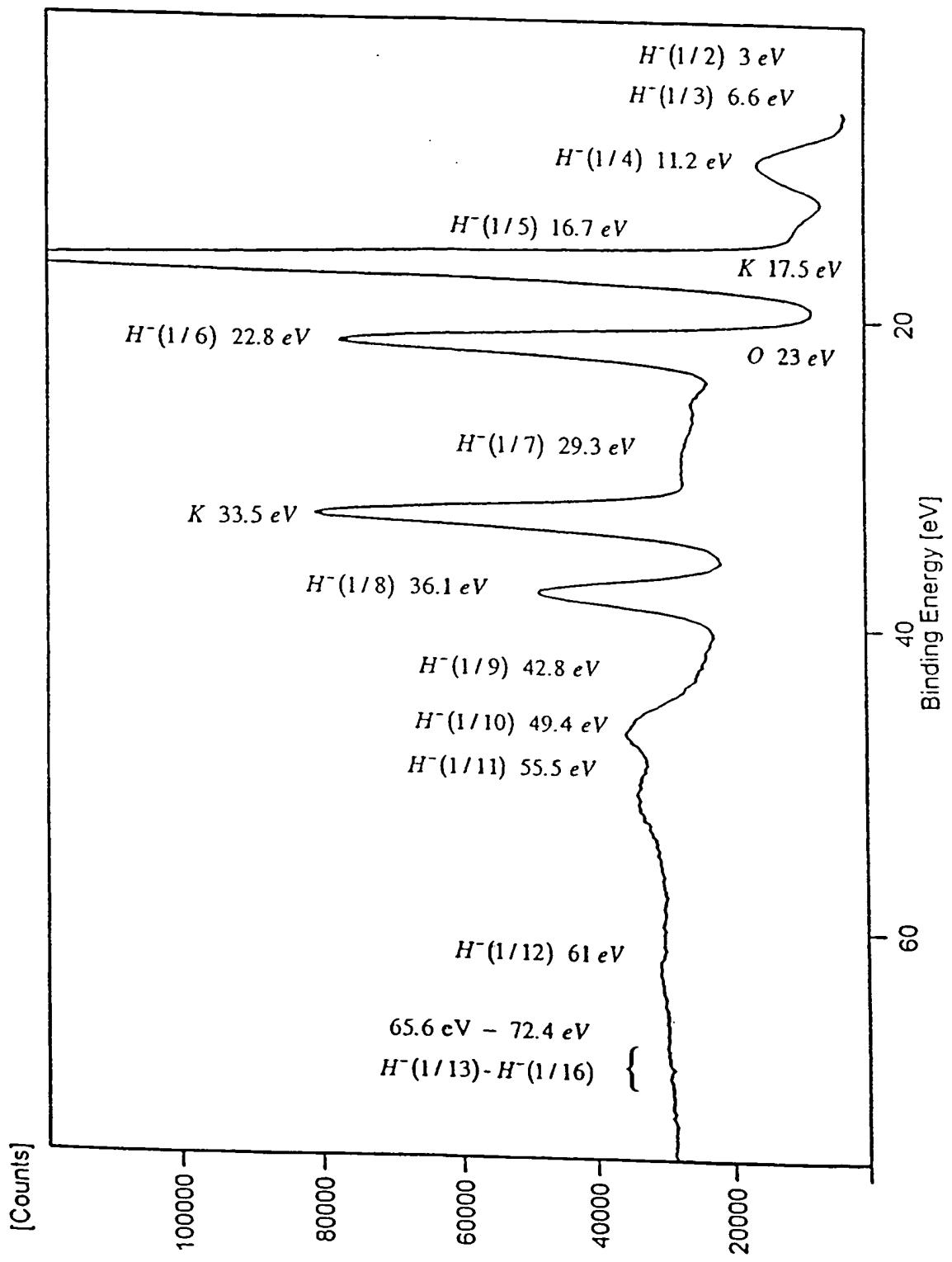


Fig. 100

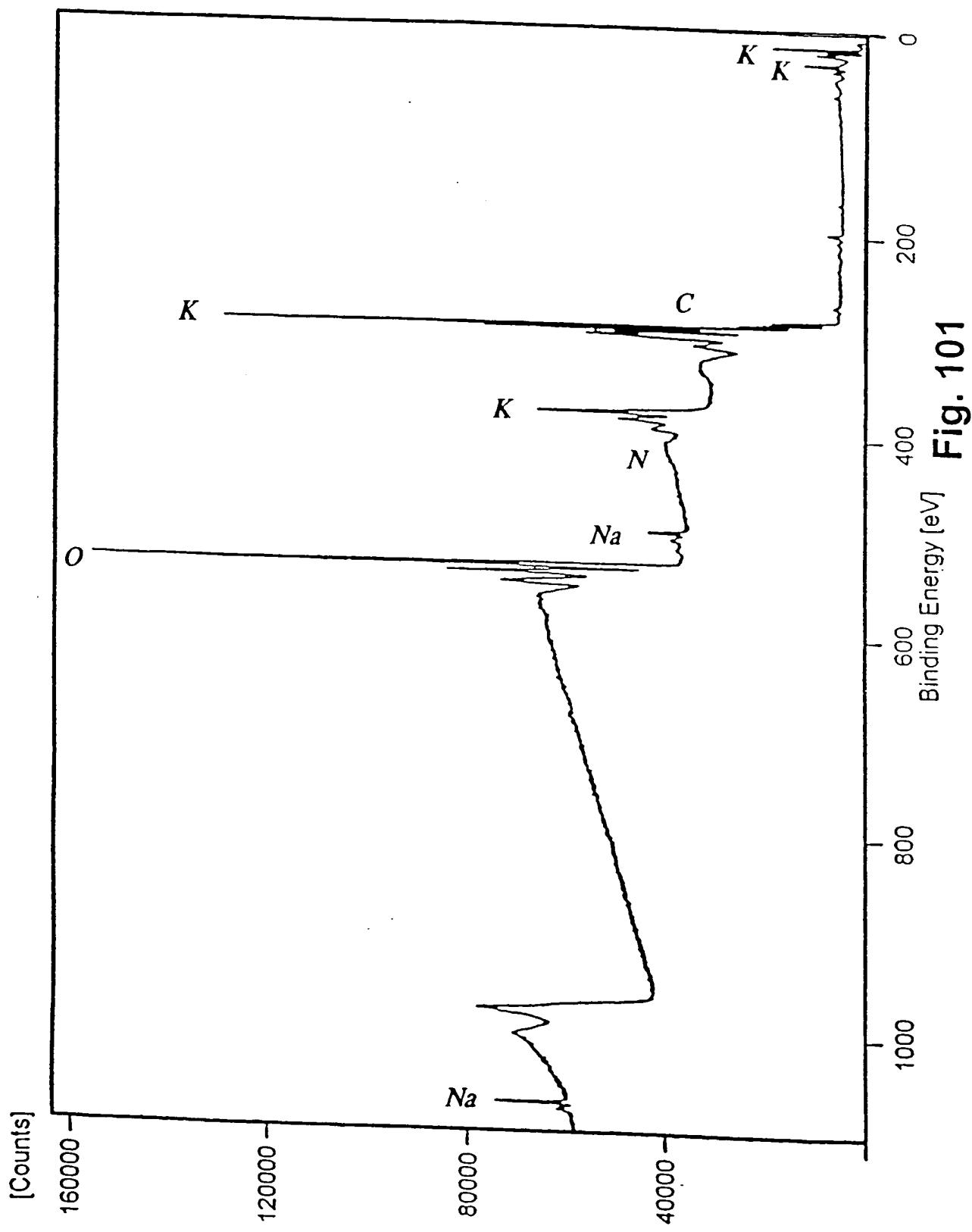


Fig. 101

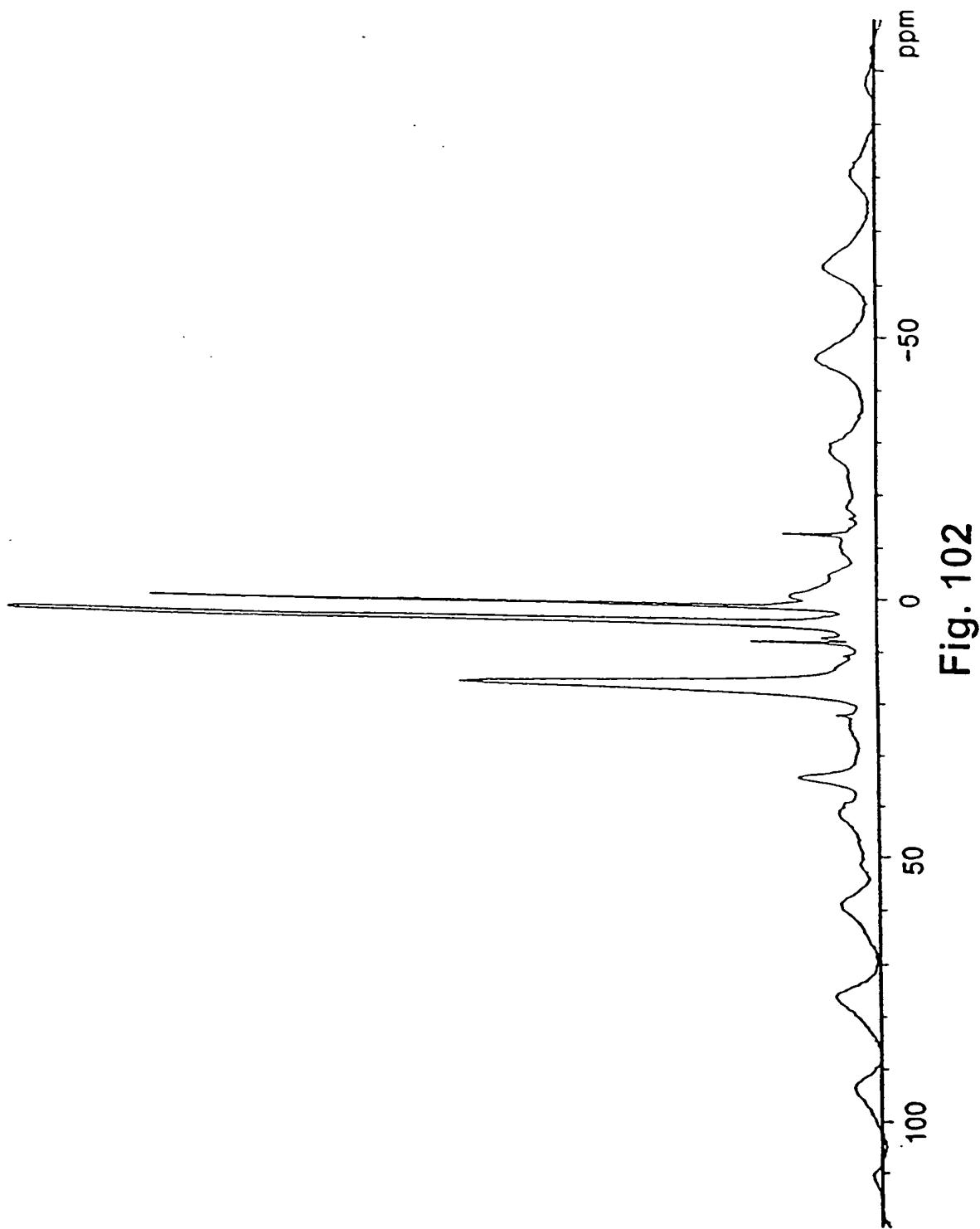
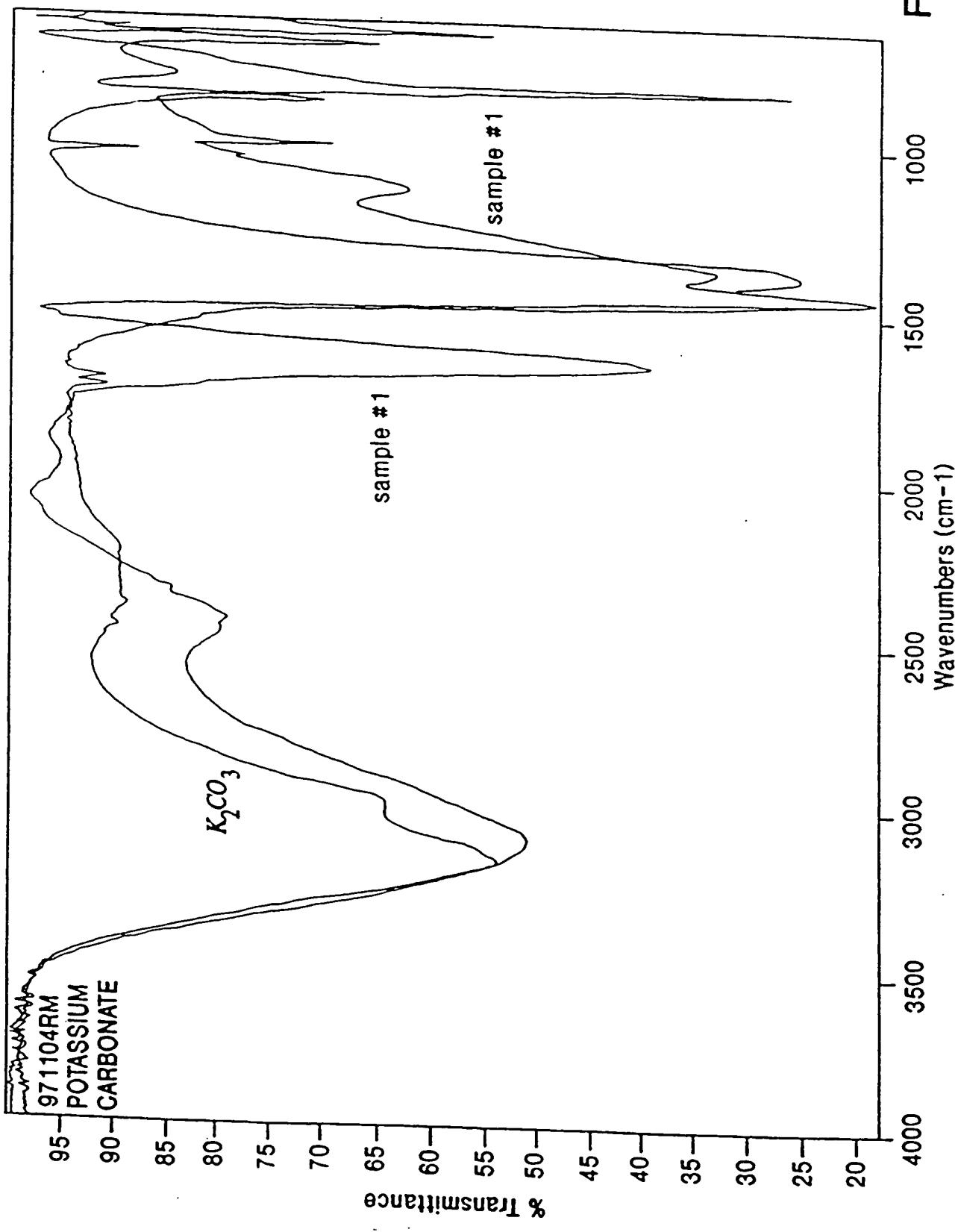


Fig. 102

Fig. 103



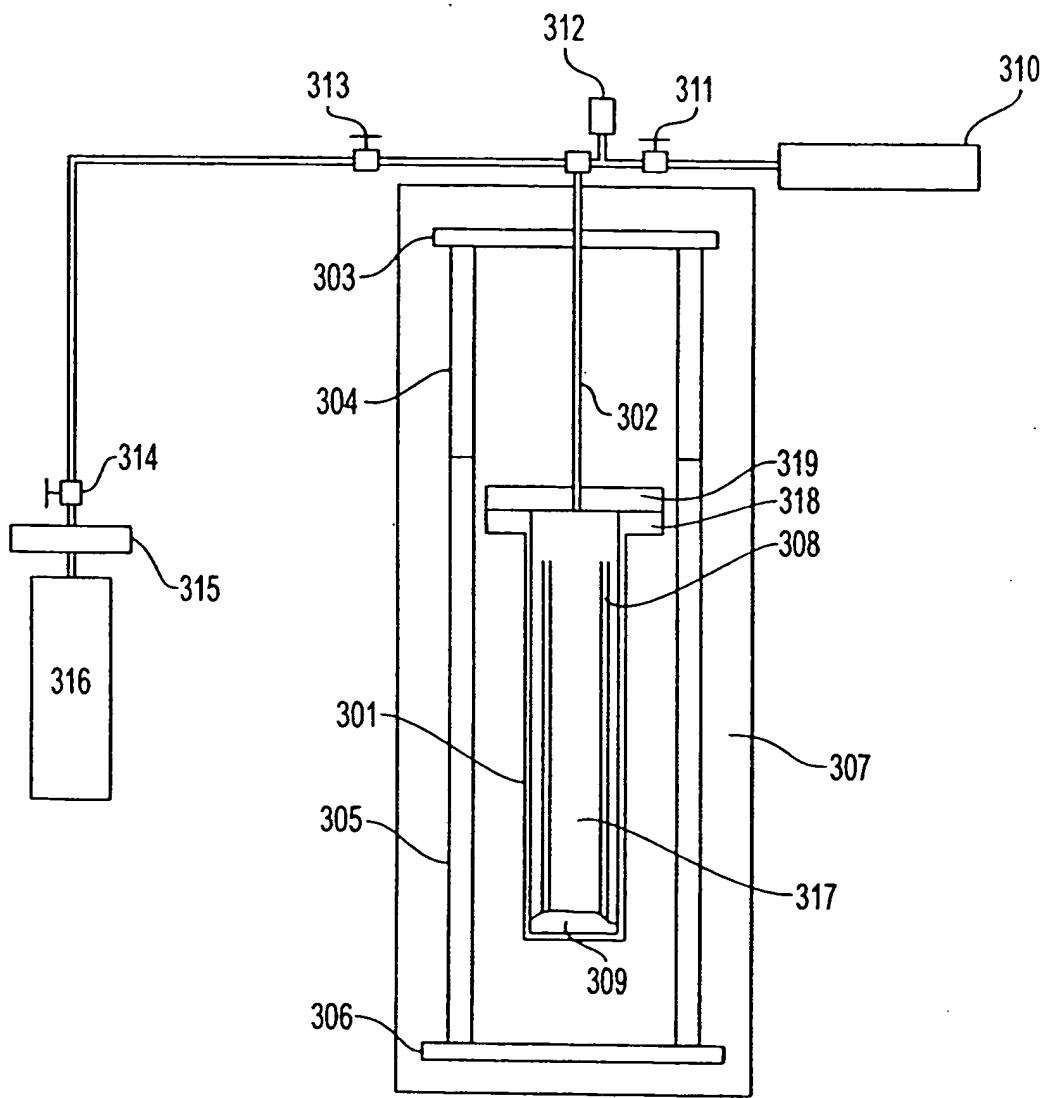


FIG. 104

FIG. 105A

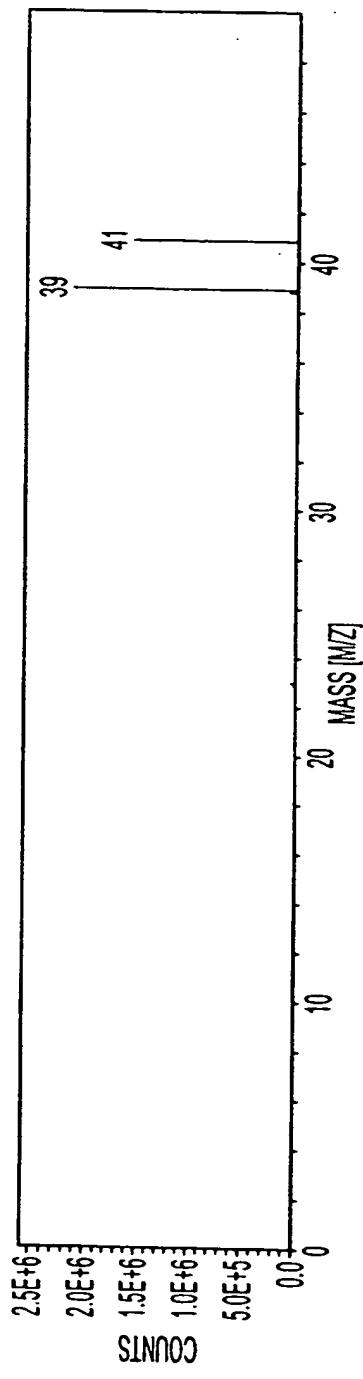


FIG. 105B

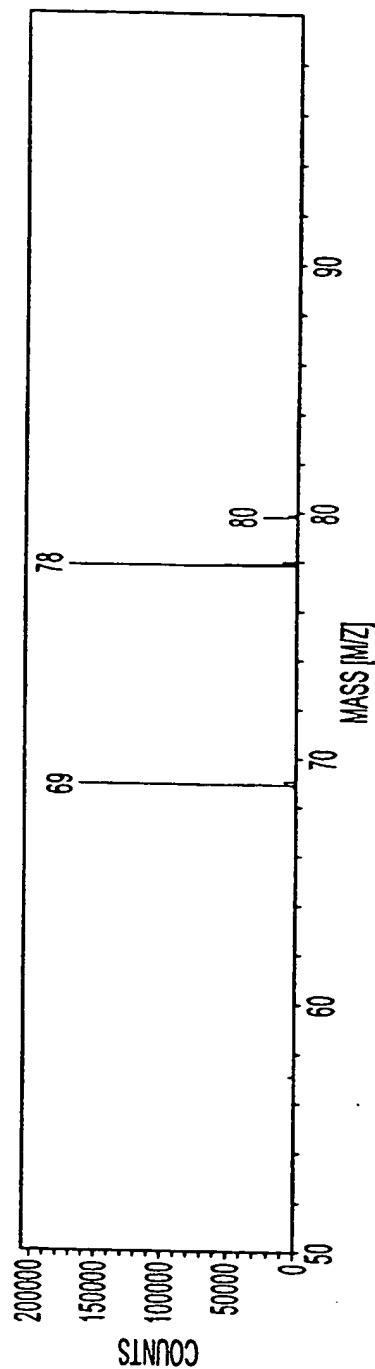


FIG. 105C

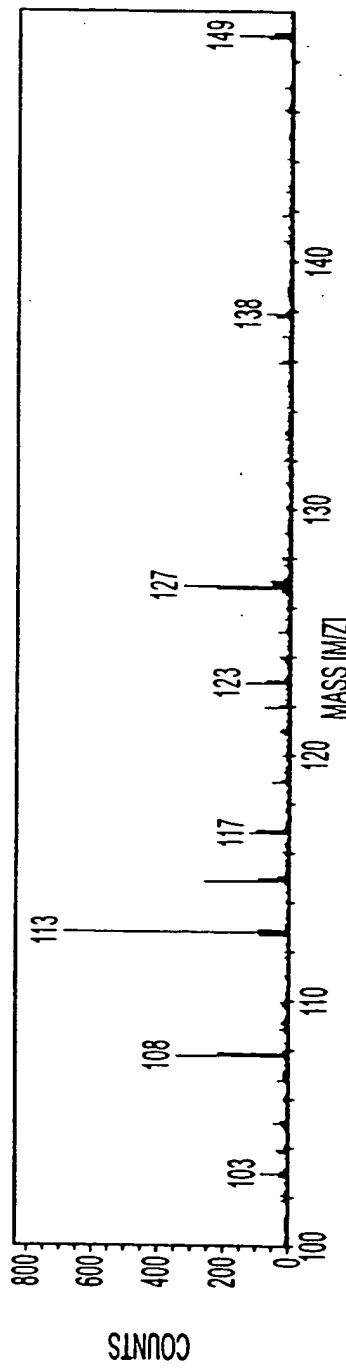


FIG. 105D

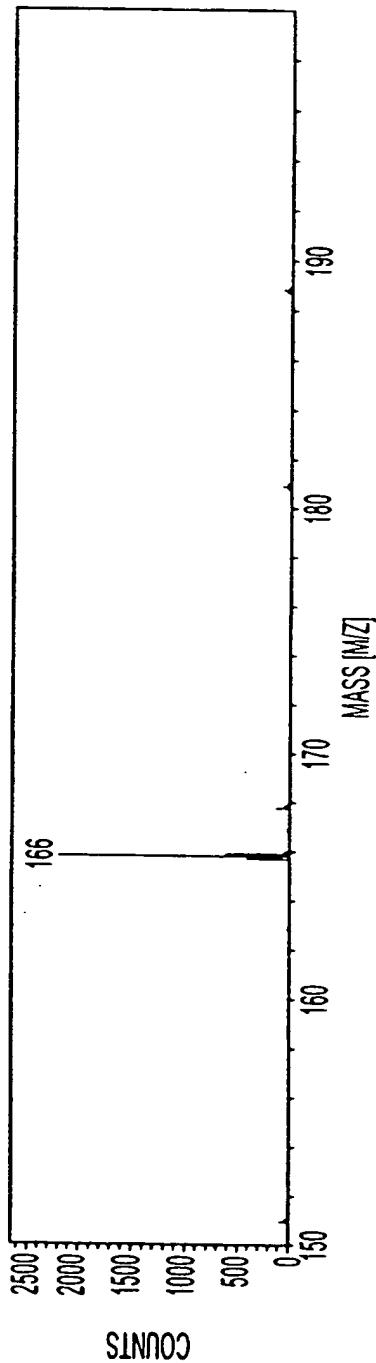


FIG. 106A

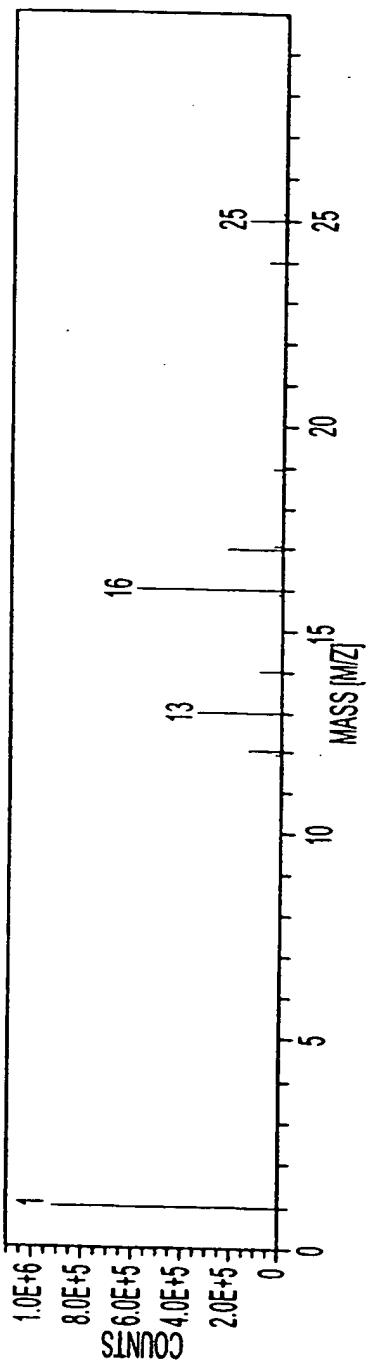


FIG. 106B

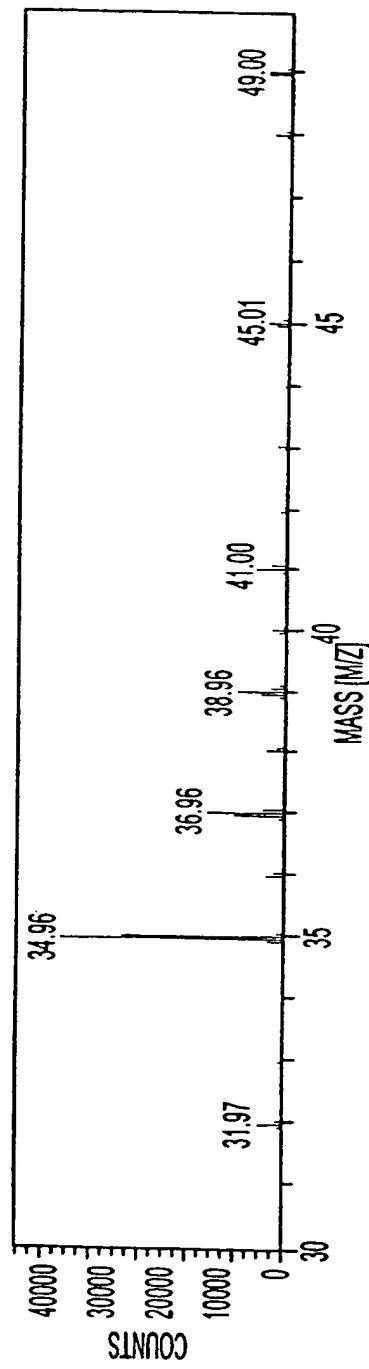


FIG. 106C

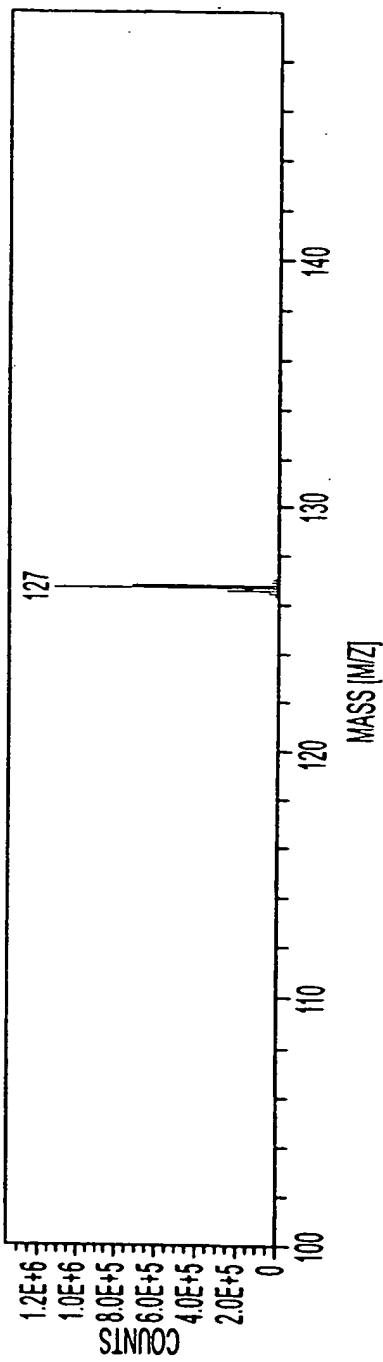
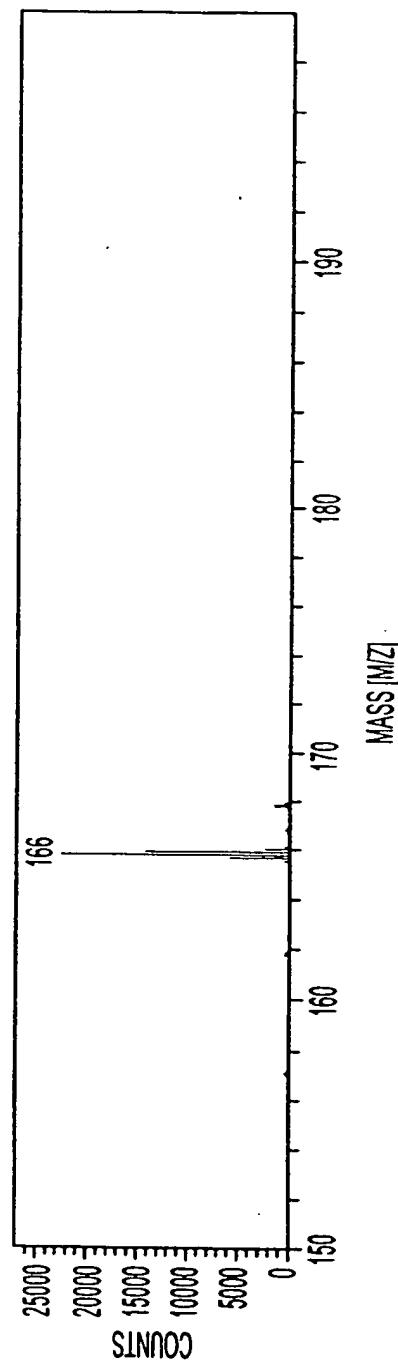


FIG. 106D



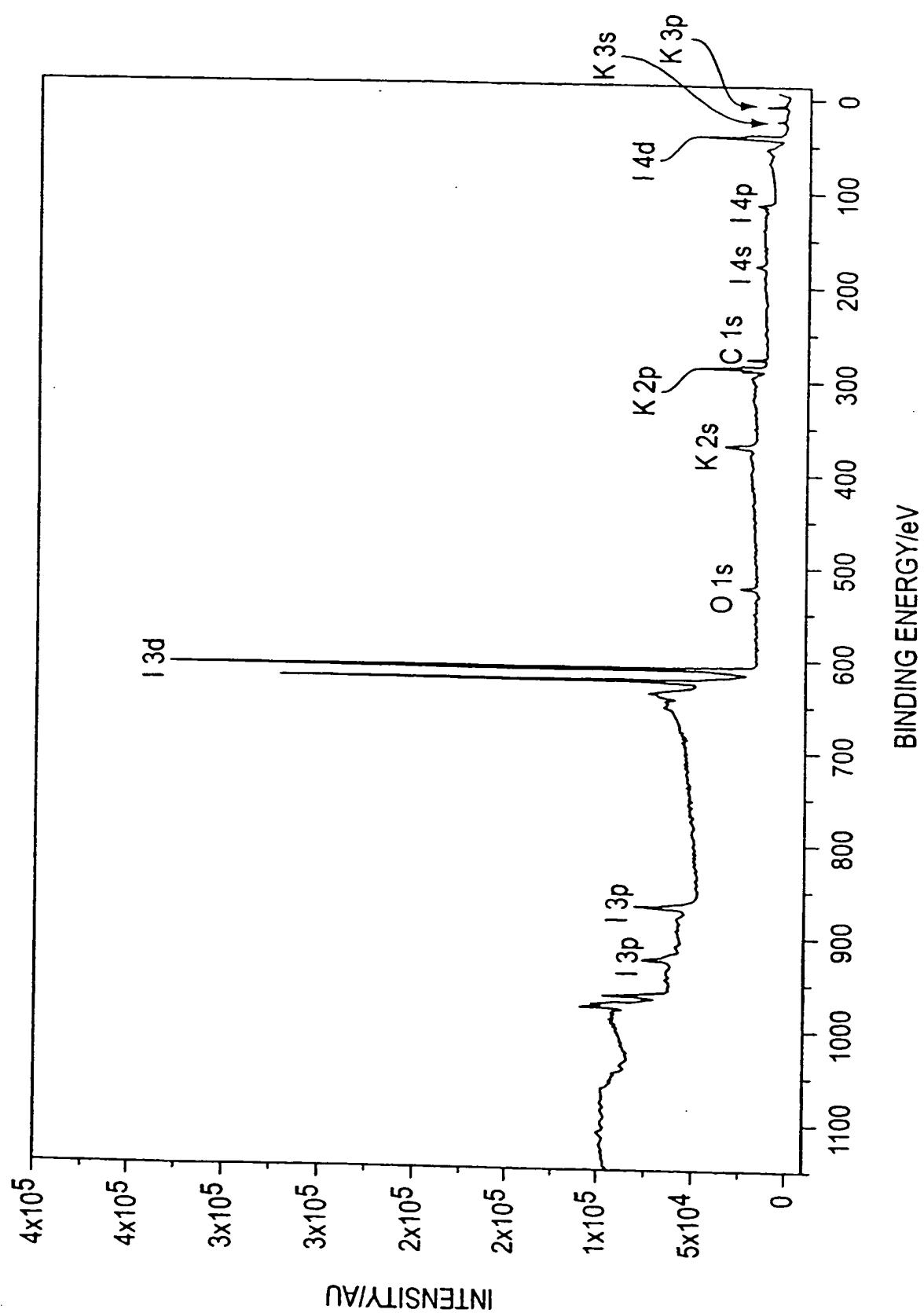


FIG. 107

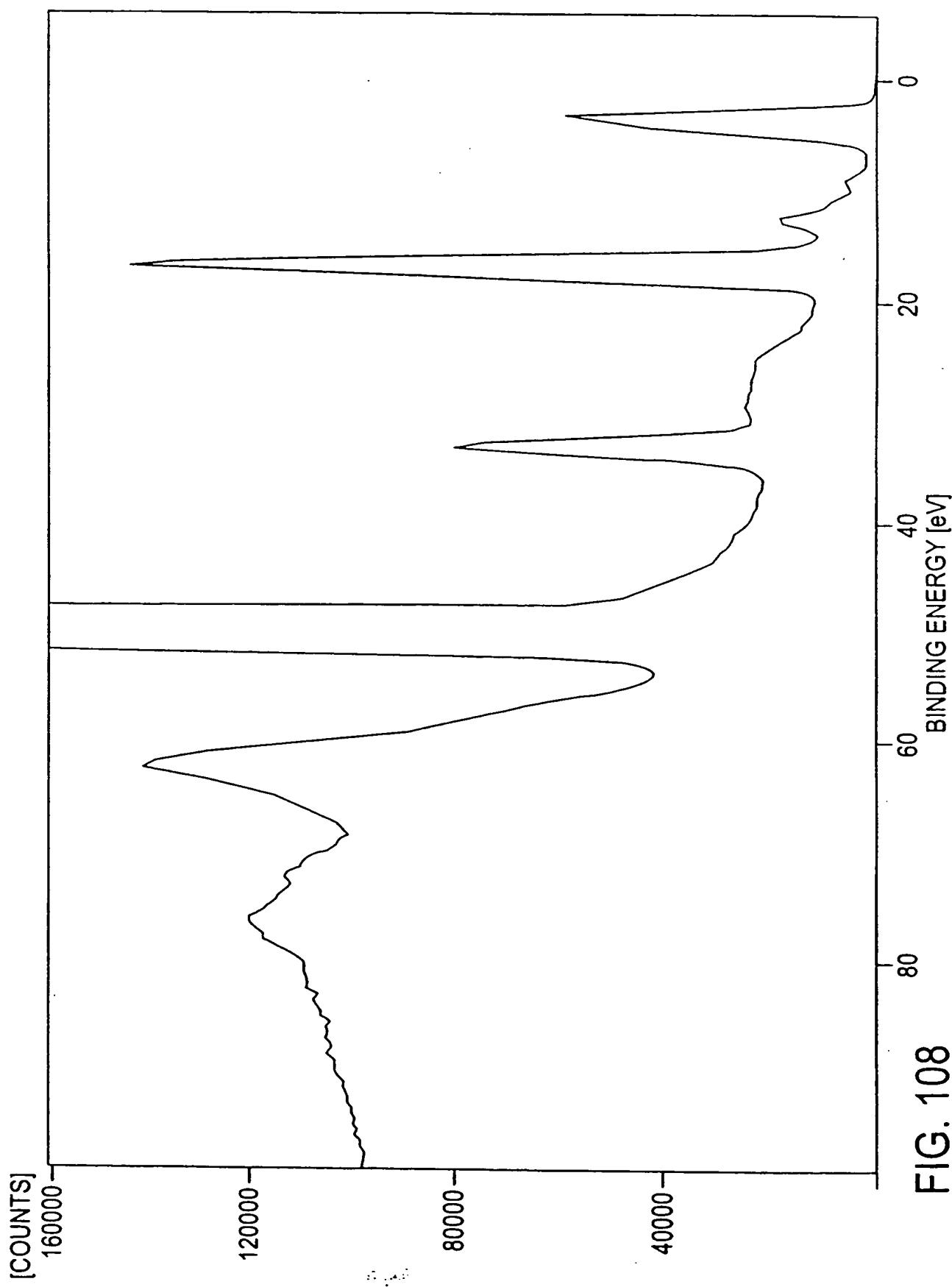


FIG. 108

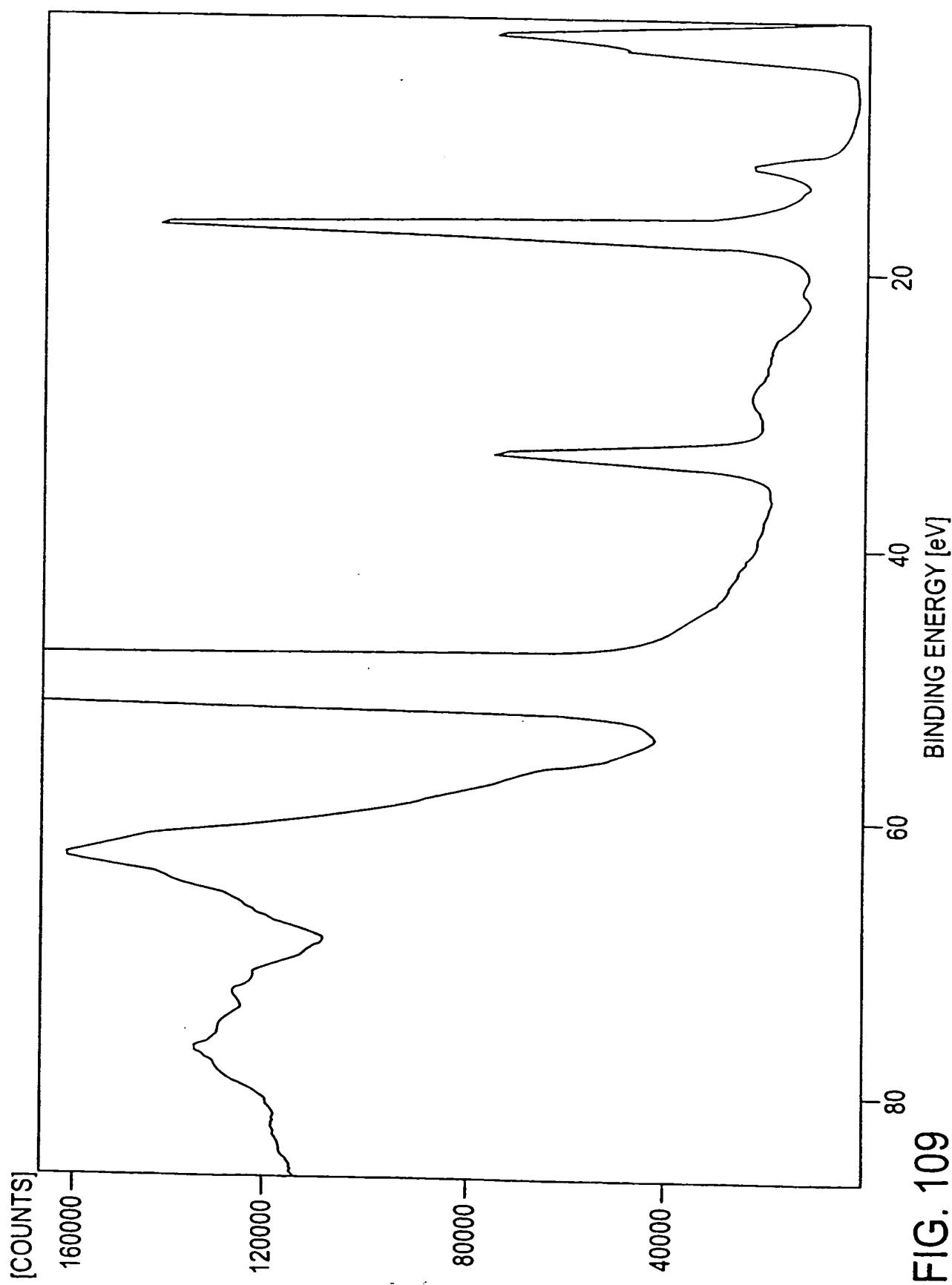


FIG. 109

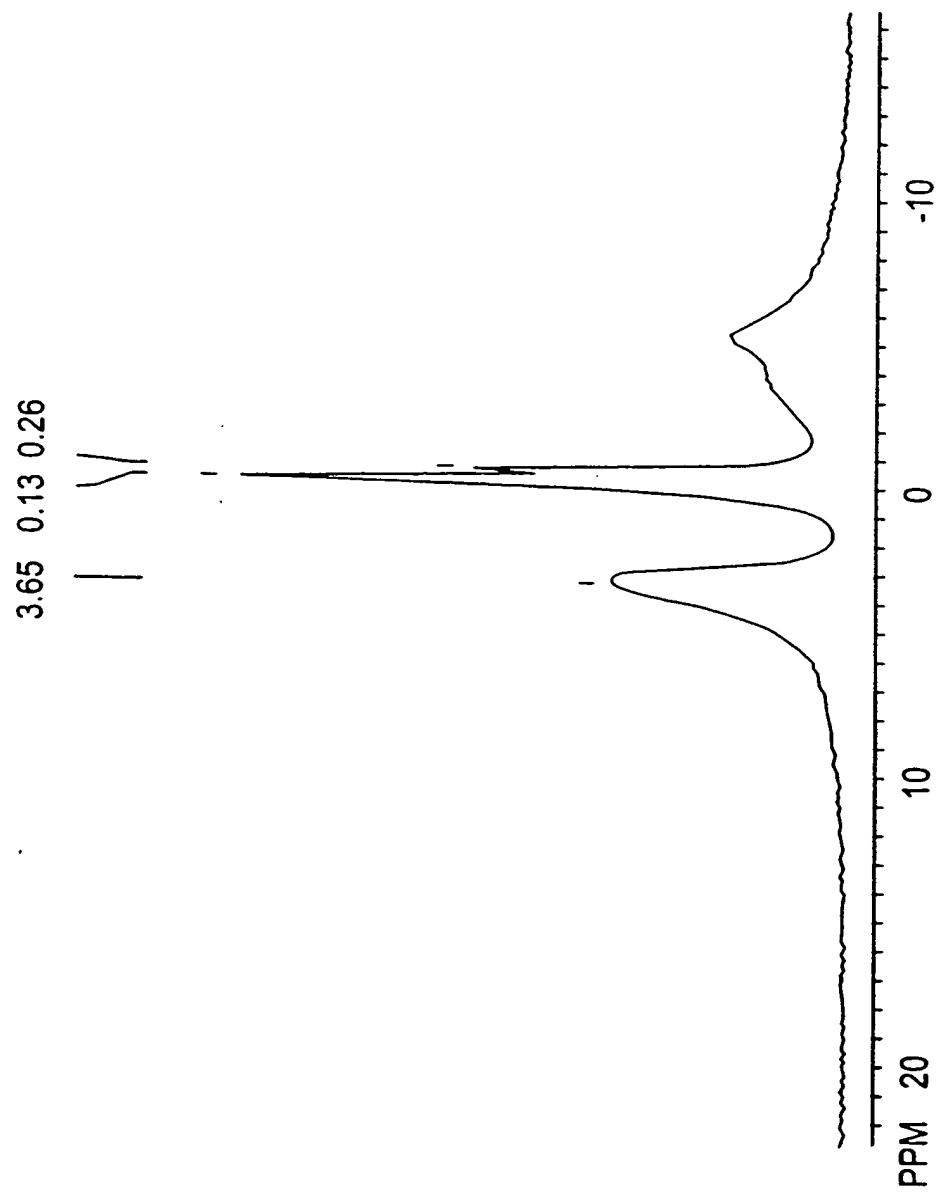


FIG. 110

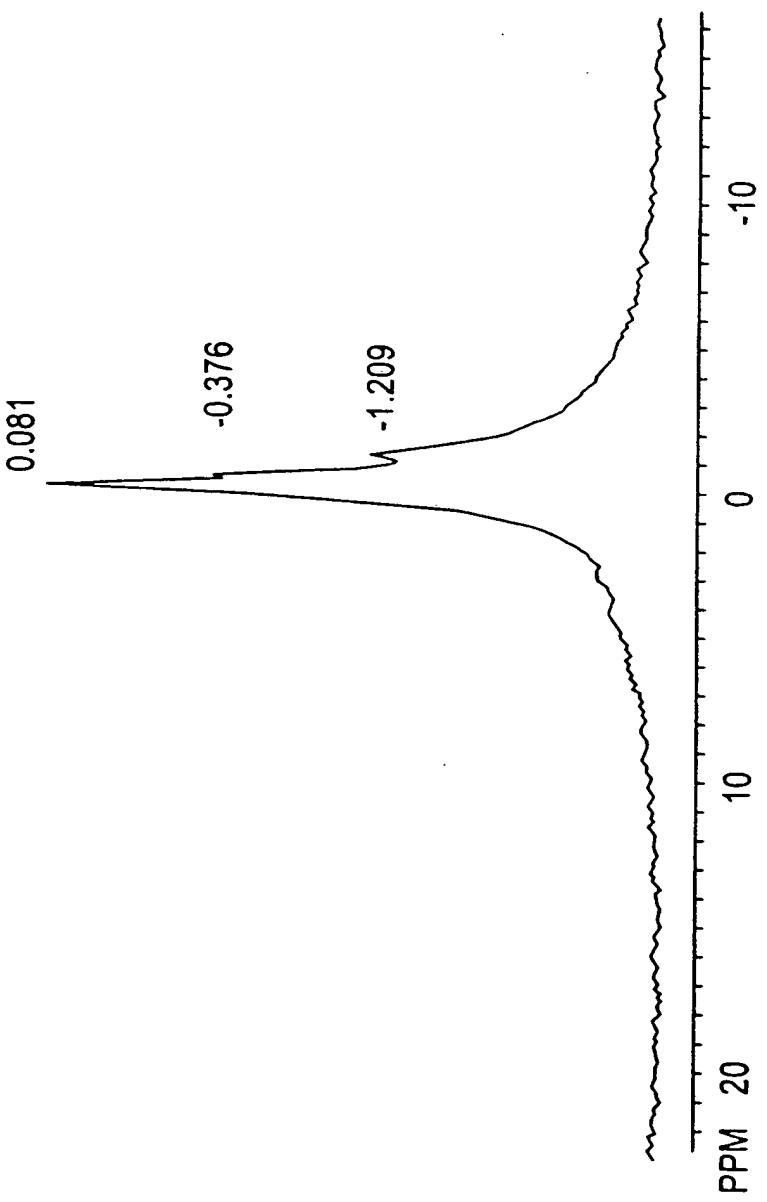


FIG. 111

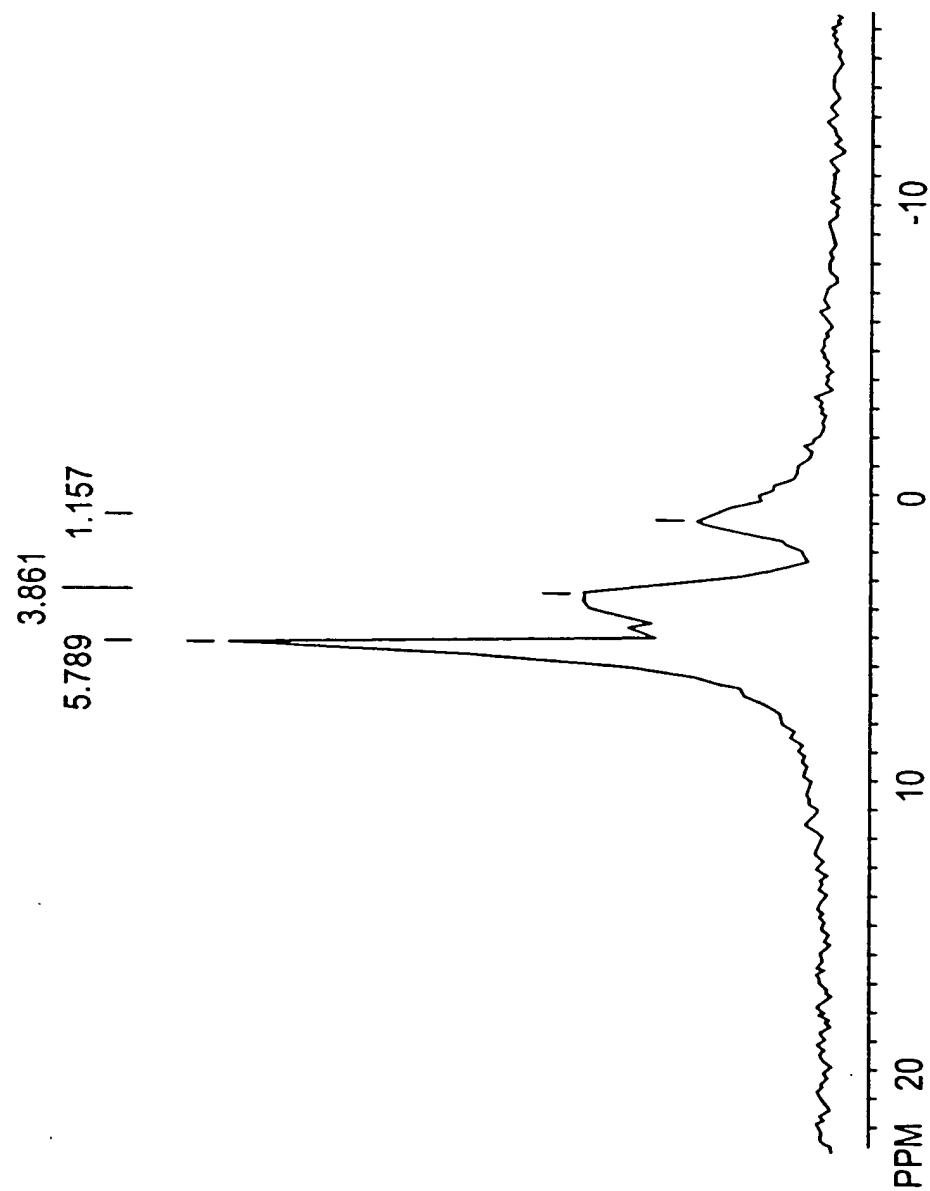


FIG. 112

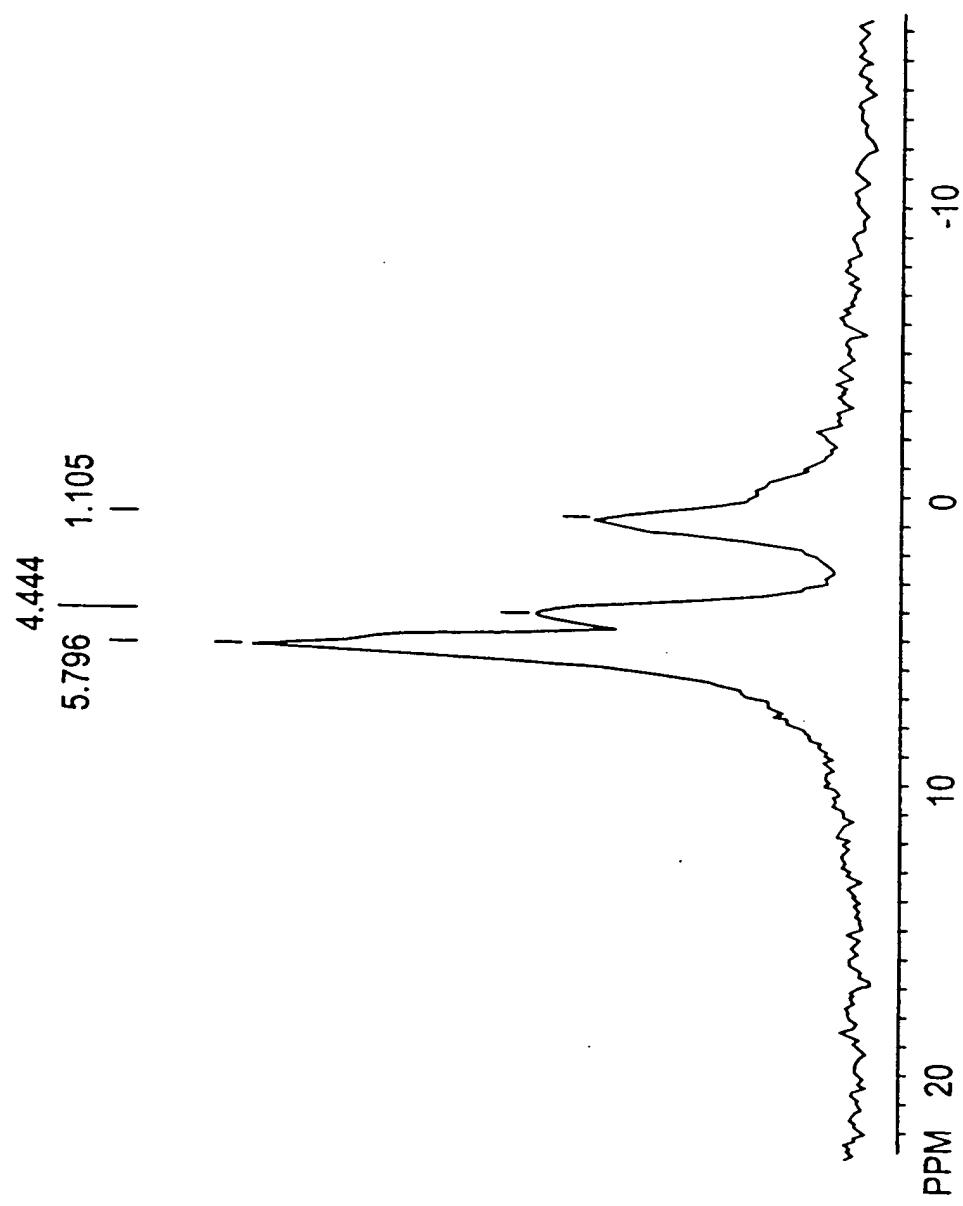


FIG. 113

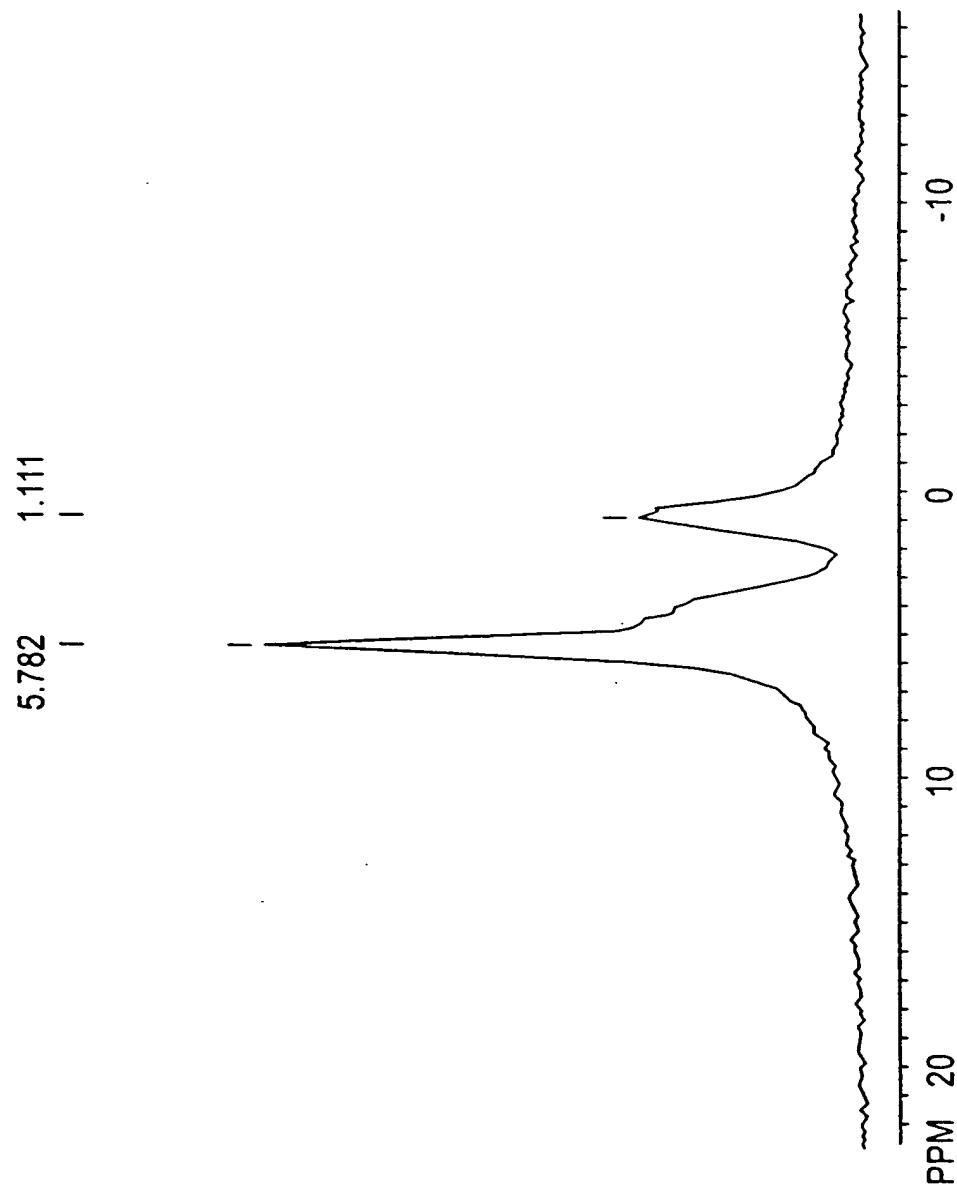


FIG. 114

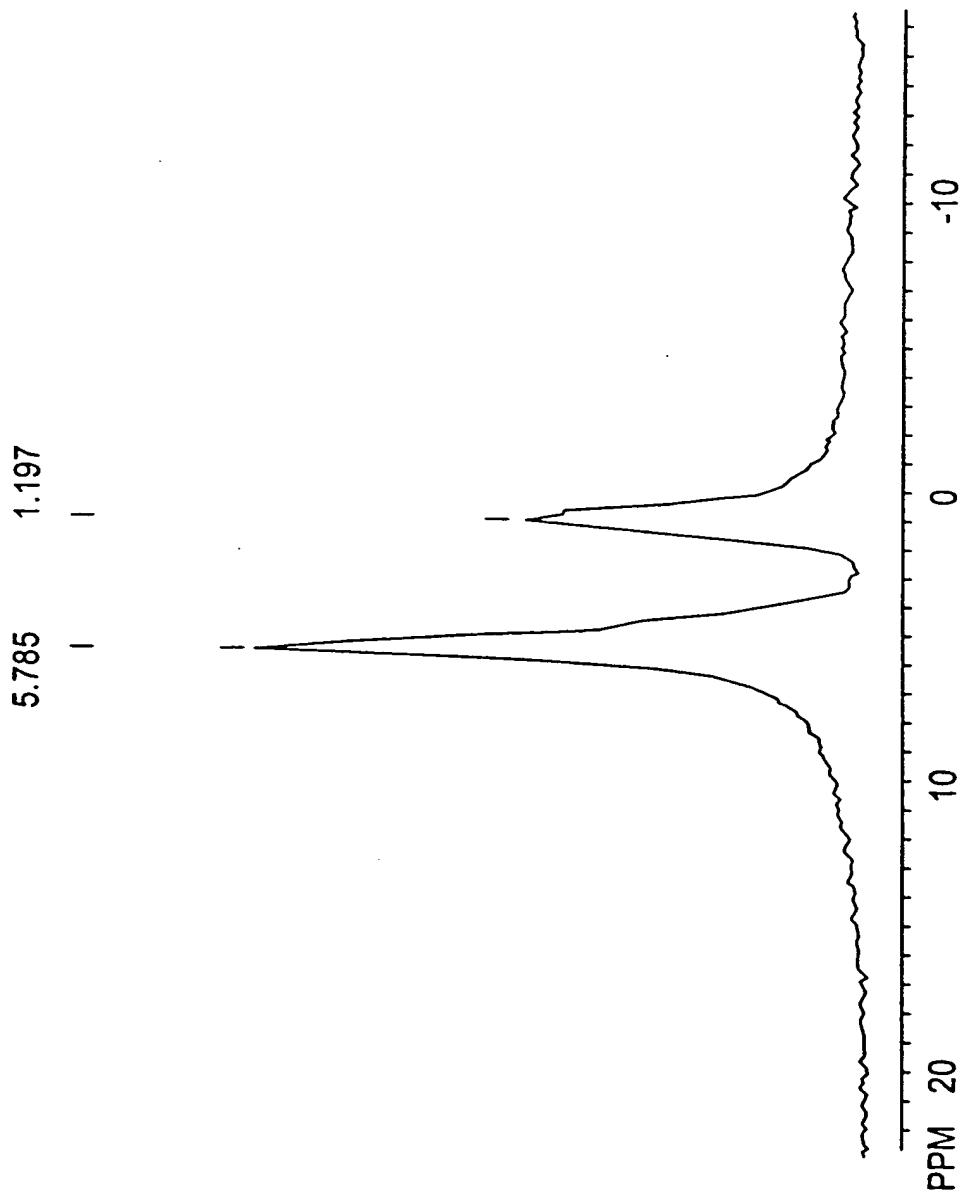


FIG. 115

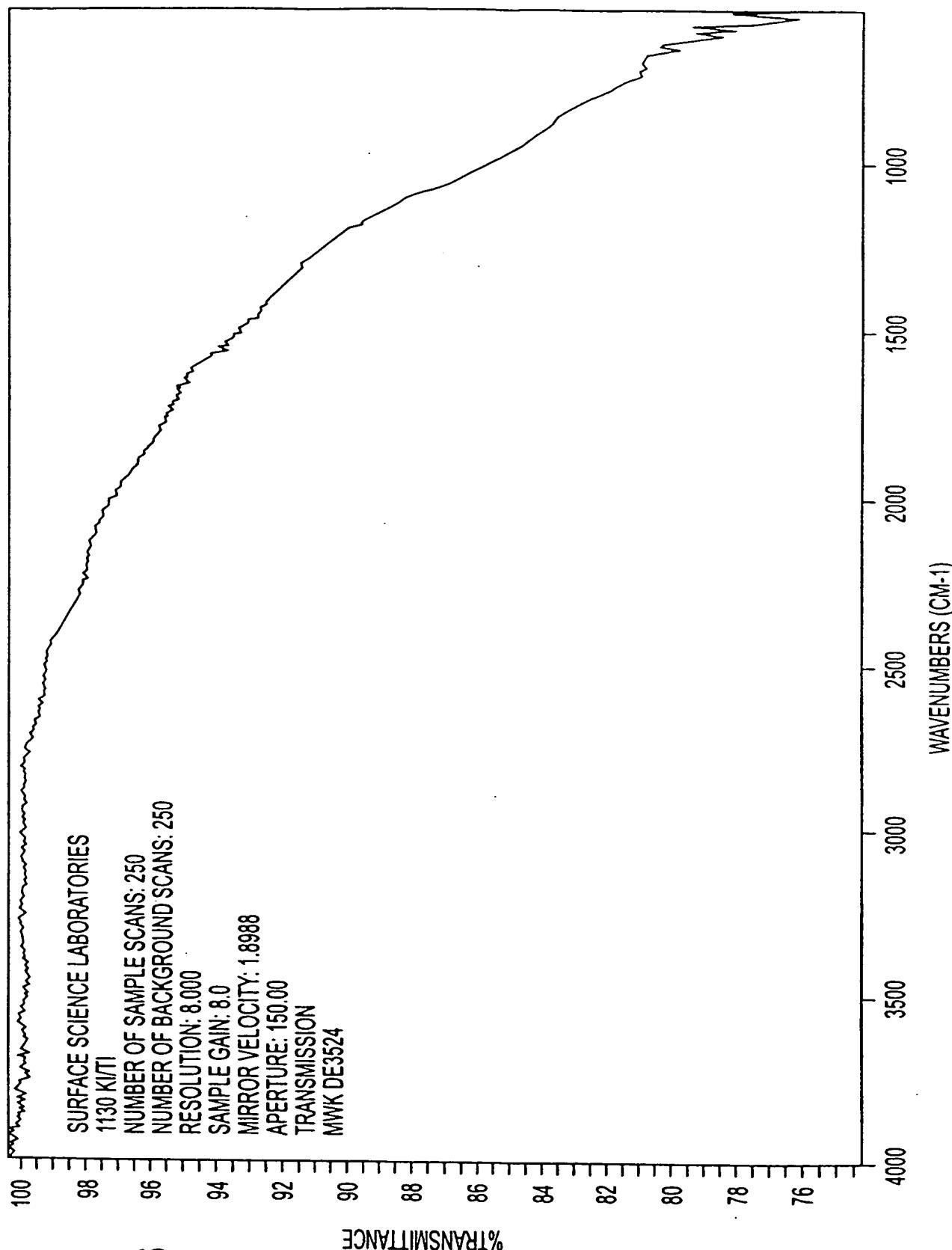


FIG. 116

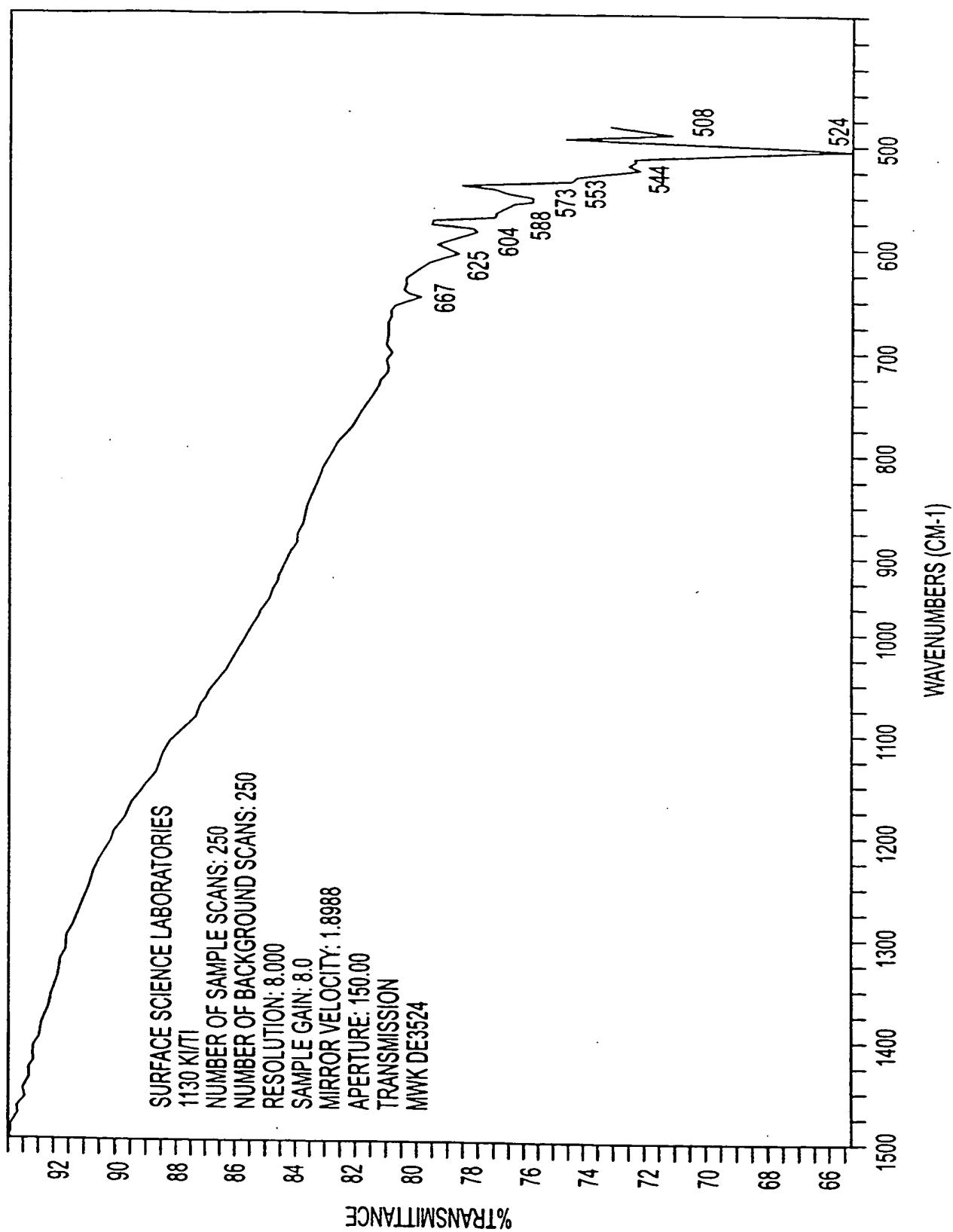


FIG. 117

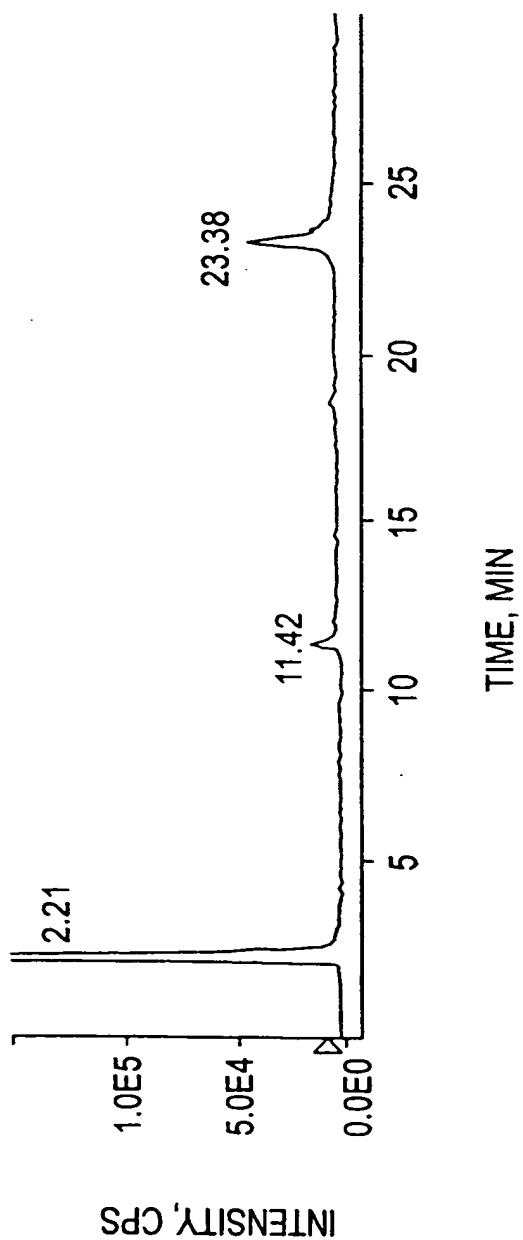


FIG. 118

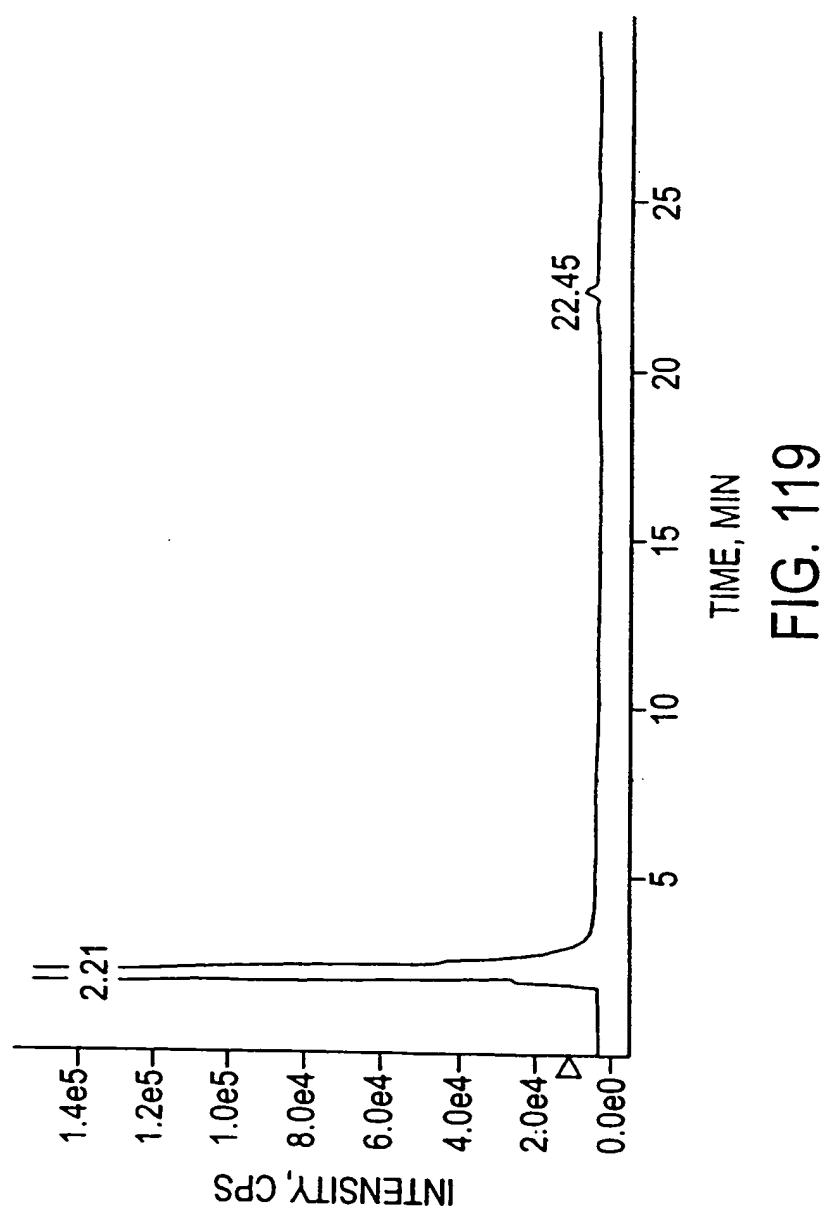
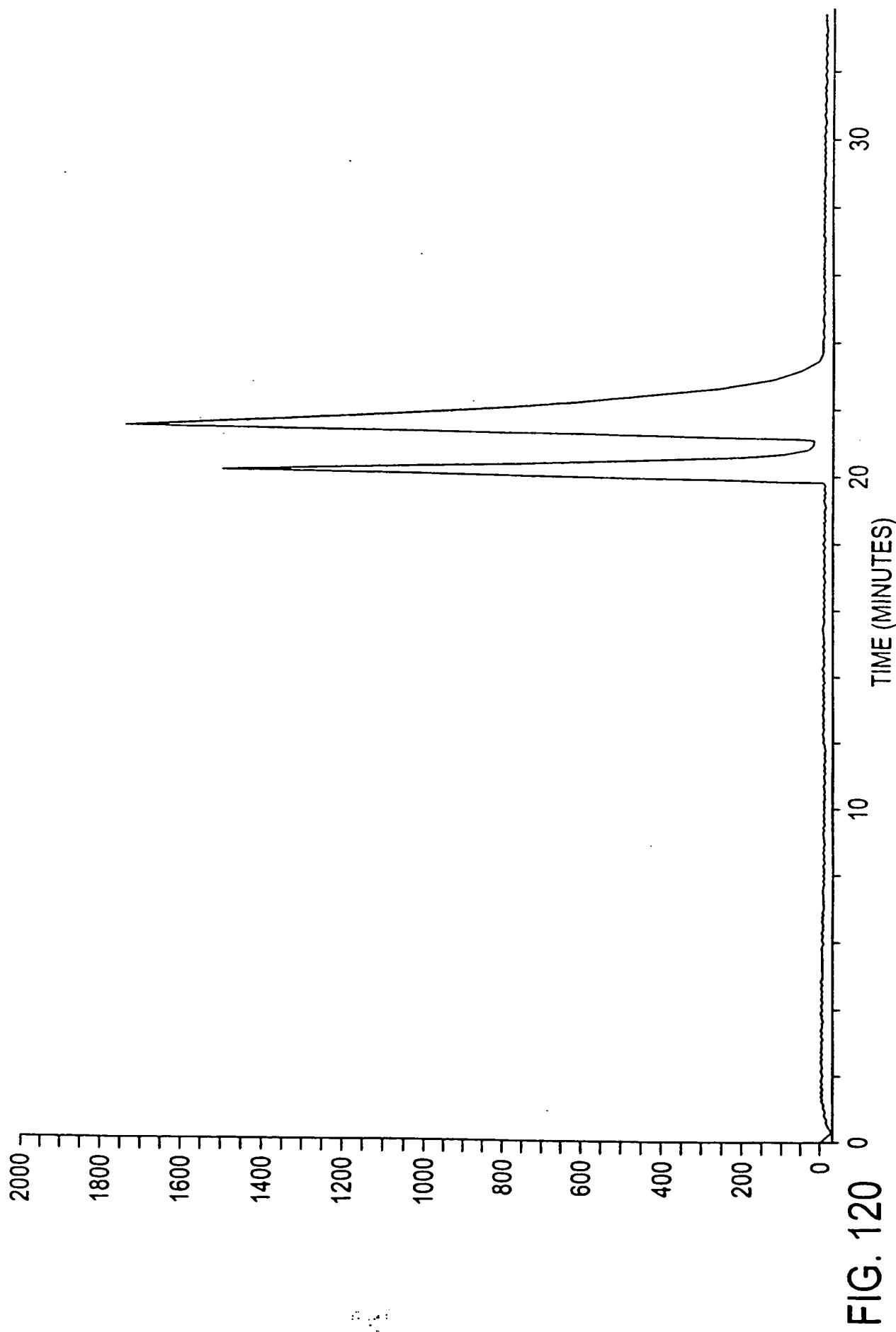


FIG. 119



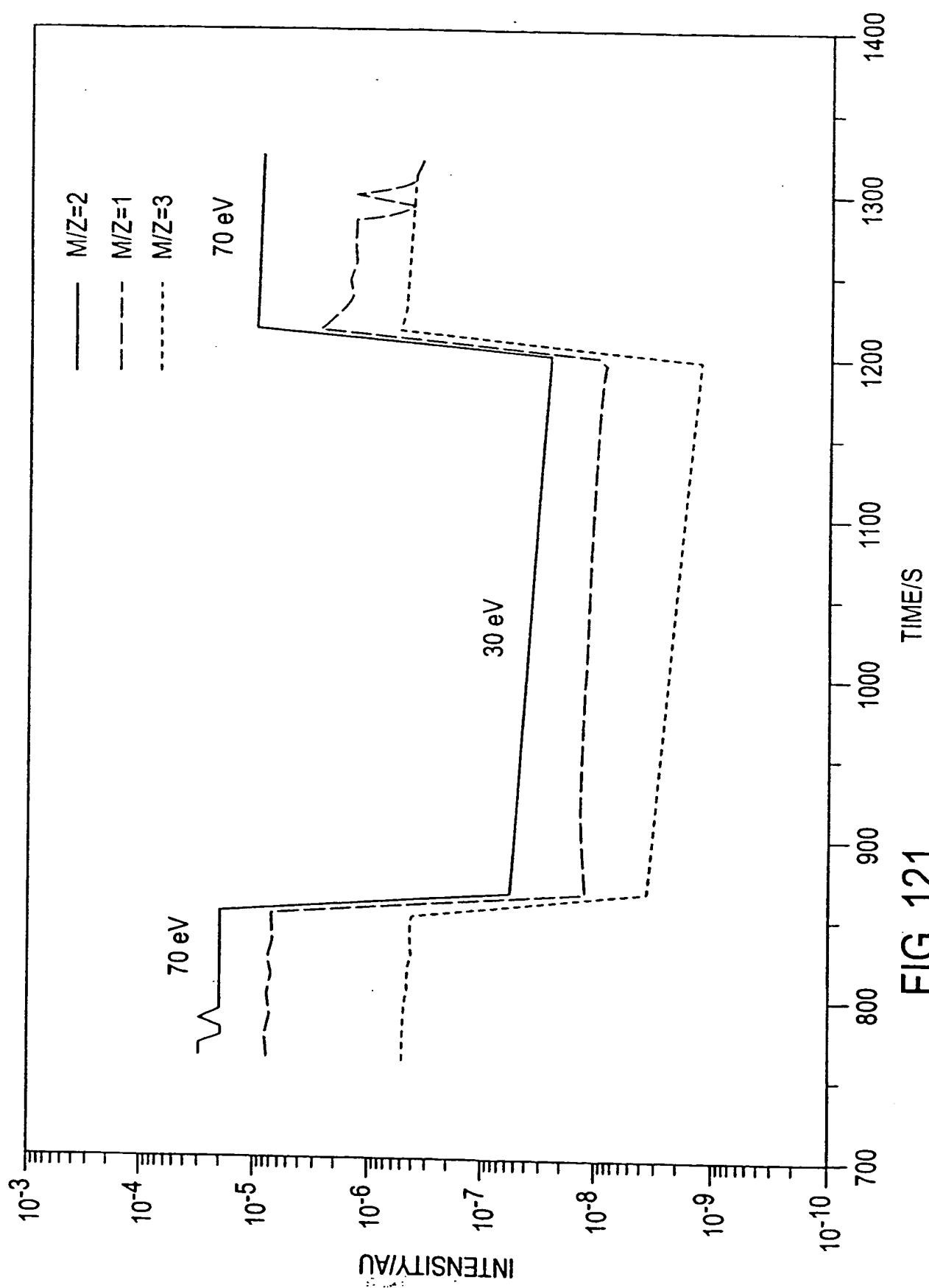


FIG. 121

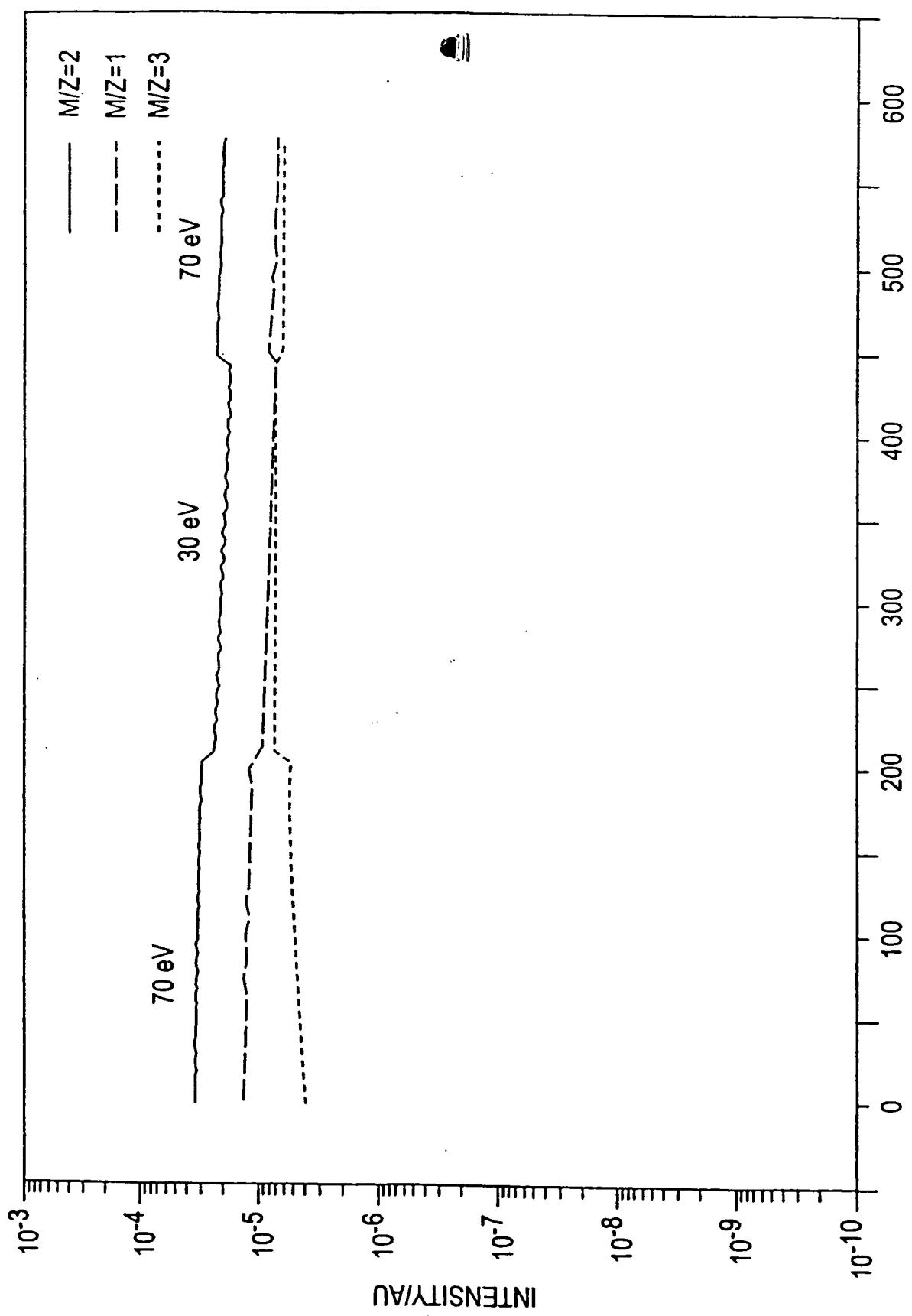


FIG. 122

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